AUDIO EXPANDER COMPRESSOR. 50-100 WATT AMPLIFIER MODULES. AUDIO LIMITER. SELECTA-GAME. AUDIO PHASER.

TOP PROJECTS

VOL. 4

from electronics today

$3·00*

POOL ALARM. TRAIN CONTROLLER. ACTIVE ANTENNA. GSR MONITOR. DYNAMIC NOISE FILTER. SELECTA-GAME. 'SCOPE TEST YOUR CAR. TEMPERATURE METER. UNIVERSAL TIMER. KITS FOR ETI PROJECTS. 50-100 WATT AMPLIFIER MODULES. GENERAL PURPOSE POWER SUPPLY. AUDIO LIMITER. TEMPERATURE ALARM.

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Editorial

Project Designs:	Barry Wilkinson
Editor:	Jan Vernon
Publisher:	Collyn Rivers
Managing Director:	Arnold Quick

Advertising

Sydney:	Tel 33-4282
Melbourne:	Tel 51-9836

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from Electronics Today

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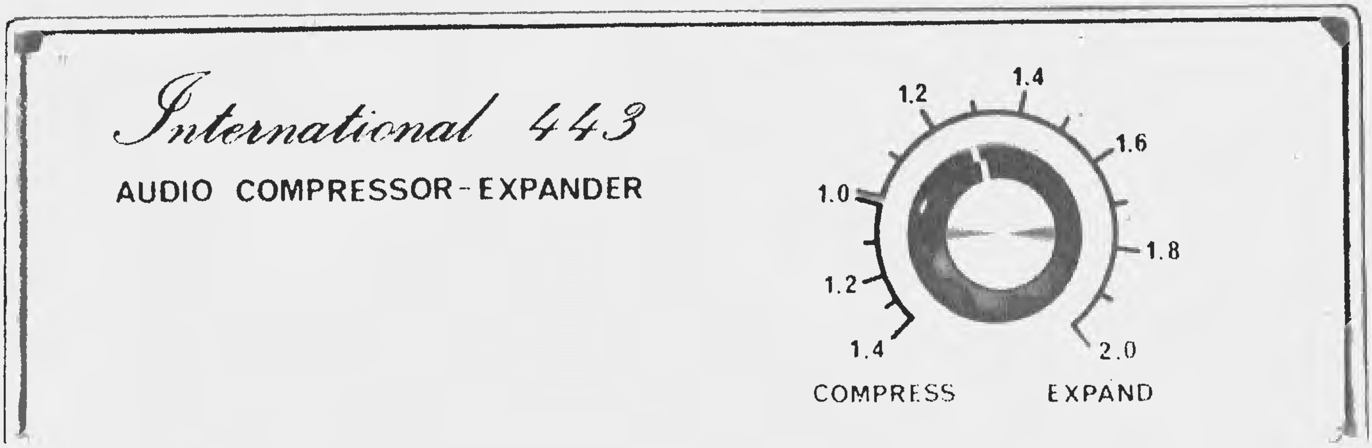
Audio expander compressor

Increase dynamic range of tape recordings and/or reduce record surface noise with this versatile unit. This project is based on an original design by Frank Gillespie of Findon, South Australia.



MANY OF US HAVE TAPES IN either the reel to reel format or on cassettes which have poor signal to noise ratio. It is not that we necessarily made a bad job of the recording in the first place, but rather the limitations of our equipment and tape were generally just a little bit too much compared with what is available today. And because the signal to noise ratio is so poor, many of these tapes (and quite a few records as well) tend to lie on the shelf because of their audible inadequacies. Apart from this it is by no means unknown for commercially pre-recorded tapes and records to be below an acceptable standard.

Many people arbitrarily think that this problem is what the Dolby system is intended to resolve. But this is not so. The Dolby system helps *maintain* the original signal to noise ratio when recording from one medium to another but it has very little to offer when faced by *existing* inadequacies.

Another problem that plagues many of us is the poor dynamic range of our tape recorders or of the pre-recorded material that we buy. For example, the majority of cassette recorders are hard pressed to offer even a 55 dB dynamic range. Many of them offer little more than 40 dB. As if this were not bad enough, very few records have a dynamic range exceeding 50-55 dB and even this is considerably degraded after a dozen or so playings in a dusty environment.

One at least partial solution to these problems is the use of dynamic volume expansion, and units are available commercially that do just this.

The dbx 117 dynamic range enhancer reviewed in ETI in January 1975 performed remarkably well – to the extent that one of our readers decided to design a dynamic volume expander – starting from basic principles.

It was decided that the cost of incorporating root mean square detection was not justified – so absolute mean detection was used instead.

Our reader's unit was then passed over to our development laboratory who made minor changes to the circuitry and designed suitable metalwork etc.

The final unit described here is relatively inexpensive to build, yet its performance is quite adequate for all practical purposes. It is sufficiently versatile to interface with most existing audio equipment, at nominal signal levels from about 25 millivolts to 1 volt.

CONSTRUCTION

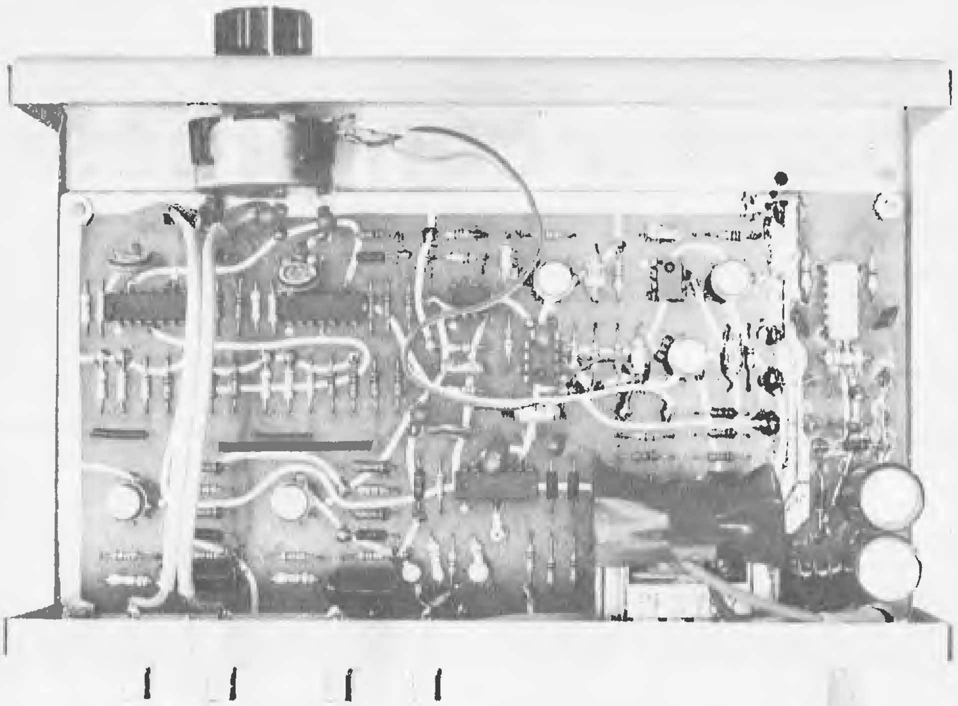
Due to the relative complexity of the circuit a double-sided printed-circuit board has been used to simplify the construction, and we strongly recommend that this board be used. A single-sided board could be used but it would be much larger and would require a great number of wire links.

Begin construction by assembling the components on to the board following the component overlay. Take particular care with the orientation of components as marked on the overlay. When soldering component leads to the top of the printed-circuit board use a soldering iron which has a small tip and use a small gauge of solder (1 mm recommended). Take care not to bridge solder between the IC pads. It is easy to miss soldering connections on the component side of the board and these should be double checked.

Take care to insert the electrolytics with the polarity as marked on the overlay and even more care with the orientation of the diodes. A reversed diode can result in the destruction of one of the dual transistors.

The resistors in the signal side of the circuit and those in the current-sink circuit should be 2% or better.

Audio expander compressor



Alternatively they may be selected from 5% values. In selecting values an ordinary multimeter (operated at about the centre of the range suffices). The resistors in question are all those values between R37 and R65.

For best results the two 12 volt zeners should also be matched but in practice any slight discrepancy may readily be compensated by using the normal stereo-balance control.

As explained below, capacitor C5 should be chosen in accordance with the particular compromise that suits the user of the unit. Alternately a switch may be used to select different values. A value of 1 microfarad for C5 allows compression or expansion to follow the signal amplitude so rapidly that the ear is unlikely to detect the attack or release, which is virtually complete in about 20 milliseconds. However, with this value, low frequency signal components (50 Hz or lower) will not be averaged out in obtaining the gain-control voltage, and severe intermodulation and 3rd harmonic distortion will result. At the other extreme, a value of 4.7 microfarads for C5 will prevent such distortion right down to the lower audible limit, but the attack and release time (about 100 milliseconds) is long enough so that the control effects can be audible, although not necessarily unpleasant. Nevertheless for the small compression or expansion ratios which should be most used, a value of C5 equal to 4.7 microfarads will be found quite acceptable by most people.

Potentiometer RV1 is a trimpot used to match the signal levels of the compressor-expander with those of the associated equipment.

The box used in our prototype was 200 x 125 x 63 mm and, although a little crammed, did adequately hold the unit. The next larger box available was thought to be too big. The printed-circuit board is mounted at the rear of the box to allow room for the front-panel potentiometer to be mounted. The board is mounted on 6 mm spacers and the transformer is then mounted directly onto the rear panel together with the RCA input and output sockets.

POWER SUPPLY

The output of the transformer is rectified by a full-wave bridge to provide ±22 volts as set by the zener diodes. The voltages obtained from the MC1468 voltage regulator are near enough to the nominal ± 15 volts for correct operation of the compressor-expander.

SETTING UP

With the power supply connected (check for correct polarity), apply a strong (about 1 volt) audio signal to both stereo inputs, while the point marked 'X' is shorted to ground. Monitor the left channel output with a high sensitivity meter (or amplifier) and adjust RV3 to the point where the output *just* disappears. Repeat with the right channel and RV4. This procedure balances out the input offset voltage of the current sinks, and ensures that the audio gain will be controlled correctly at the low end. Remove the input signal and the short circuit.

Potentiometer RV1 is a trimpot, this is set by the following procedure:

(1) Connect the compressor-expander to its associated equipment, and supply an input of moderate level (e.g. music of average loudness). Potentiometer RV1 should be fully clockwise when viewed from the input edge of the board.

(2) Turn the compress-expand control to full compression, and adjust RV1 to bring the output up to its original level (loudness).

(3) Turn the compress-expand control towards the expansion end, and note any obvious change in output level.

(4) If a decrease in level occurs, turn RV1 slightly anticlockwise; if an increase occurs, turn RV1 slightly clockwise.

(5) Repeat steps (3) and (4) until the level remains reasonably constant over the whole range of compression and expansion. Note that this adjustment is subjective, and it does not need to be done with any great accuracy.

If RV1 cannot be adjusted as described, it means that the signal level is outside the optimum range of the compressor-

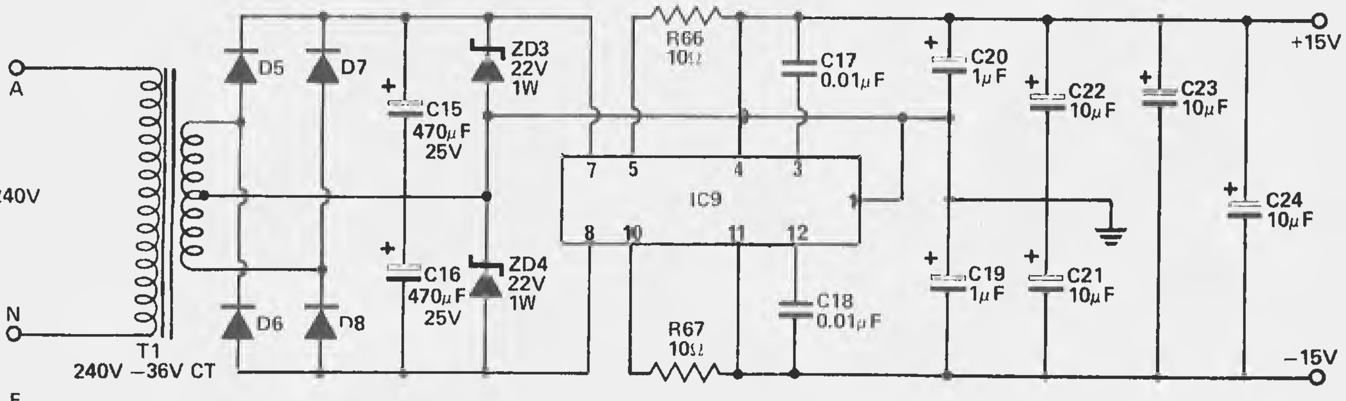
expander. Somewhat higher signal levels can be accommodated by increasing the value of R1 and R2 whilst for lower signal levels, R4 should be decreased. If correct adjustment of RV1 is obtained well towards the anticlockwise end, then an improved signal-to-noise ratio results if R34 and R36 are increased to 18k, and the stereo outputs are each attenuated by a 470 ohm/3.9 k divider. However, this modification is not essential.

With no input signal applied adjust RV2 such that the voltage at its wiper is zero volts. Now fit the knob such that the pointer lines up with the 1.0 calibration. Check that the potentiometer travel approximately matches the scale. If not reverse the two outside leads of RV2.

HOW TO USE

The use of a compressor-expander need not be confined to those situations where such a device is really needed. Practically all tapes and many records become more listenable with a small amount of expansion. On the other hand, background music is far less obtrusive if the volume is compressed to some extent. The key to listening pleasure lies in the handling of the compress-expand control. Don't move it far from the 1.0 position unless there is some definite reason.

One final word of warning – on full expansion this device is quite capable of outputting a signal of 10 volts. It would be wise to ensure that your amplifier is capable of accepting this voltage without damage if full expansion is ever used.



NOTES
D5–D8 ARE EM401 OR SIMILAR
ZD3,ZD4 ARE 22V 1W ZENERS
IC9 IS MC1468L,SG4501N, XR1568

Circuit diagram for the power supply section. (On the same board as the circuitry of Fig. 1).

KITS FOR ETI PROJECTS

We get many enquiries from readers wanting to know where they can get kits for the projects we publish. The list below indicates the suppliers we know about and the kits they do.

Any companies who want to be included in this list should phone Steve Braidwood on 33-4282.

Key to companies:

- **A** Applied Technology Pty. Ltd of Hornsby, NSW.
- **C** Amateur Communications Advancements, PO Box 57, Rozelle, NSW.
- **D** Dick Smith Pty. Ltd. of Crows Nest, NSW.
- **E** E.D. & E. Sales, Victoria.
- **J** Jaycar Pty. Ltd. of Haymarket, NSW.
- **L** Delsound Pty. Queensland.
- **N** Nebula Electronics Pty. Ltd. of Rushcutters Bay, NSW.
- **O** Appollo Video Games of Hornsby, NSW.
- **P** Pre-Pak Electronics of Croydon, NSW

PROJECT ELECTRONICS

ETI 043	Heads or Tails	A
ETI 044	Two-Tone Doorbell	A
ETI 061	Simple Amplifier	A
ETI 064	Intercom	A
ETI 066	Temperature Alarm	A
ETI 068	LED Dice	A

TEST EQUIPMENT

ETI 101	Logic Power Supply	E
ETI 102	Audio Signal Generator	E,D
ETI 103	Logic Probe	E
ETI 107	Widerange Voltmeter	E
ETI 108	Decade Resistance Box	E
ETI 109	Digital Frequency Meter	E
ETI 111	IC Power Supply	E
ETI 112	Audio Attenuator	E
ETI 113	7-Input Thermocouple Meter	P,E
ETI 116	Impedance Meter	E
ETI 117	Digital Voltmeter	E,A
ETI 118	Simple Frequency Counter	E,A
ETI 119	5 V Switching Regulator supply	E
ETI 120	Logic Probe	L,E
ETI 121	Logic Pulser	L,E
ETI 122	Logic Tester	E
ETI 123	CMOS Tester	E
ETI 124	Tone Burst Generator	E
ETI 128	Audio Millivoltmeter	L,E
ETI 129	RF Signal Generator	L,F
ETI 131	General Purpose power supply	E,N
ETI 132	Power Supply	N

SIMPLE PROJECTS

ETI 206	Metronome	E
ETI 218	Monophonic Organ	E,D
ETI 219	Siren	E
ETI 220	Siren	E
ETI 222	Transistor Tester	E
ETI 232	Courtesy Light Extender	E
ETI 234	Simple Intercom	E
ETI 236	Code Practice Oscillator	E
ETI 239	Breakdown Beacon	E

MOTORISTS' PROJECTS

ETI 301	Vari-Wiper	E
ETI 302	Tacho Dwell	E
ETI 303	Brake-light Warning	E
ETI 309	Battery Charger	P,E
ETI 312	CDI Electronic Ignition	P,E
ETI 313	Car Alarm	E,D

AUDIO PROJECTS

ETI 401	Audio Mixer FET Four Input	E
ETI 402	Guitar Sound Unit	E
ETI 406	One Transistor Receiver	E
ETI 407	Bass Amp	E
ETI 408	Spring Reverb Unit	E
ETI 410	Super Stereo	E
ETI 412	Music Calibrator	E
ETI 411	100 Watt Guitar Amp	P,L,F,J,D
ETI 413	x 200 Watt Bridge Amp	F
ETI 414	Master Mixer	E,J
ETI 414	Stage Mixer	E
ETI 416	25 Watt Amplifier	E
ETI 417	Amp Overload Indicator	E
ETI 419	Guitar Amp Pre Amp.	P,E,D
ETI 420	Four-channel Amplifier	L,E
ETI 420F	SQ Decoder	E
ETI 422	International Stereo Amp	L,F,D
ETI 422B	Booster Amp	E
ETI 422	50 Watt Power Module	E
ETI 423	Add-on Decoder Amp	E
ETI 424	Spring Reverberation Unit	L,E
ETI 425	Integrated Audio System.	E
ETI 426	Rumble Filter	F
ETI 427	Graphic Equaliser	L,F,J
ETI 430	Microphone Line Amp	E
ETI 433	Active Crossover	E,J
ETI 435	Crossover Amp	F,J
ETI 438	Audio Level Meter	L,E
ETI 440	Simple 25 Watt Amp	L,E
ETI 441	Audio Noise Generator	L,E
ETI 443	Compressor-Expander	F,J
ETI 444	Five Watt Stereo	F,N
ETI 445	Preamp	J,E,D,A
ETI 446	Audio Limiter	J,E,A
ETI 447	Phaser	E,J,A
ETI 449	Balanced Mic Preamp	J,A
ETI 480	50W, 100W Power Amp	A,J,D
ETI 480 P	Power Supply	A,J,D
ETI 482A	Preamp Module	A
ETI 482B	Tone Controller	A

MISCELLANEOUS

ETI 502	Emergency Flasher	E
ETI 503	Burglar Alarm	E
ETI 505	Strobe	L,E,D
ETI 506	Infra-Red Alarm.	E
ETI 509	50-Day Timer	E
ETI 512	Photographic Timer.	E
ETI 513	Tape Slide/Synchroniser	E
ETI 514	Flash Unit Sound Operated	E
ETI 515	Flash Unit Light operated	E
ETI 518	Light Beam Alarm	E
ETI 522	Photographic Timer	E
ETI 523	Sweep Generator	E
ETI 525	Drill Speed Controller	E
ETI 526	Printimer	E
ETI 527	Touch Control Light Dimmer	E
ETI 528	Home Burglar Alarm	P,E
ETI 529	Electronic Poker Machine	E
ETI 533	Digital Display.	L,E,A
ETI 534	Calculator Stopwatch.	A,D
ETI 539	Touch Switch	E
ETI 540	Universal Timer	E
ETI 541	Train Controller.	E
ETI 543	Double Dice	A
ETI 544	Heartrate Monitor.	A

ELECTRONIC MUSIC

ETI 601 4600	Synthesiser.	J
3600	Synthesiser.	J
ETI 602	Mini Organ	E,A,D

COMPUTER PROJECTS

ETI 630	Hex Display	A
ETI 631	VDU Keyboard Encoder	A
ETI 632	VDU 1 k x 8 Memory Card	A
ETI 633	VDU Sync Generator	A

RADIO PROJECTS

ETI 701	TV Masthead Amplifier	E,D
ETI 702	Radar Intruder Alarm	D
ETI 703	Antenna Matching Unit	E
ETI 704	Crosshatch/Dot Generator	L,A,D,E
ETI 706	Marker Generator	E
ETI 707	Modern Solid State Converters	C,E
ETI 708	Active Antenna	E
ETI 710	2 metre Booster	C,E
ETI 711B	Single Relay Remote Control	A
ETI 711C	Double Relay Remote Control	A
ETI 711R	Receiver	A
ETI 711AR	Remote Control Transmitter	A
ETI 711DR	Remote Control Decoder	A
ETI 740	FM Tuner	A
ETI 780	Novice Transmitter	E

ELECTRONIC GAMES

ETI 804	Selecta-Game	O,A,D

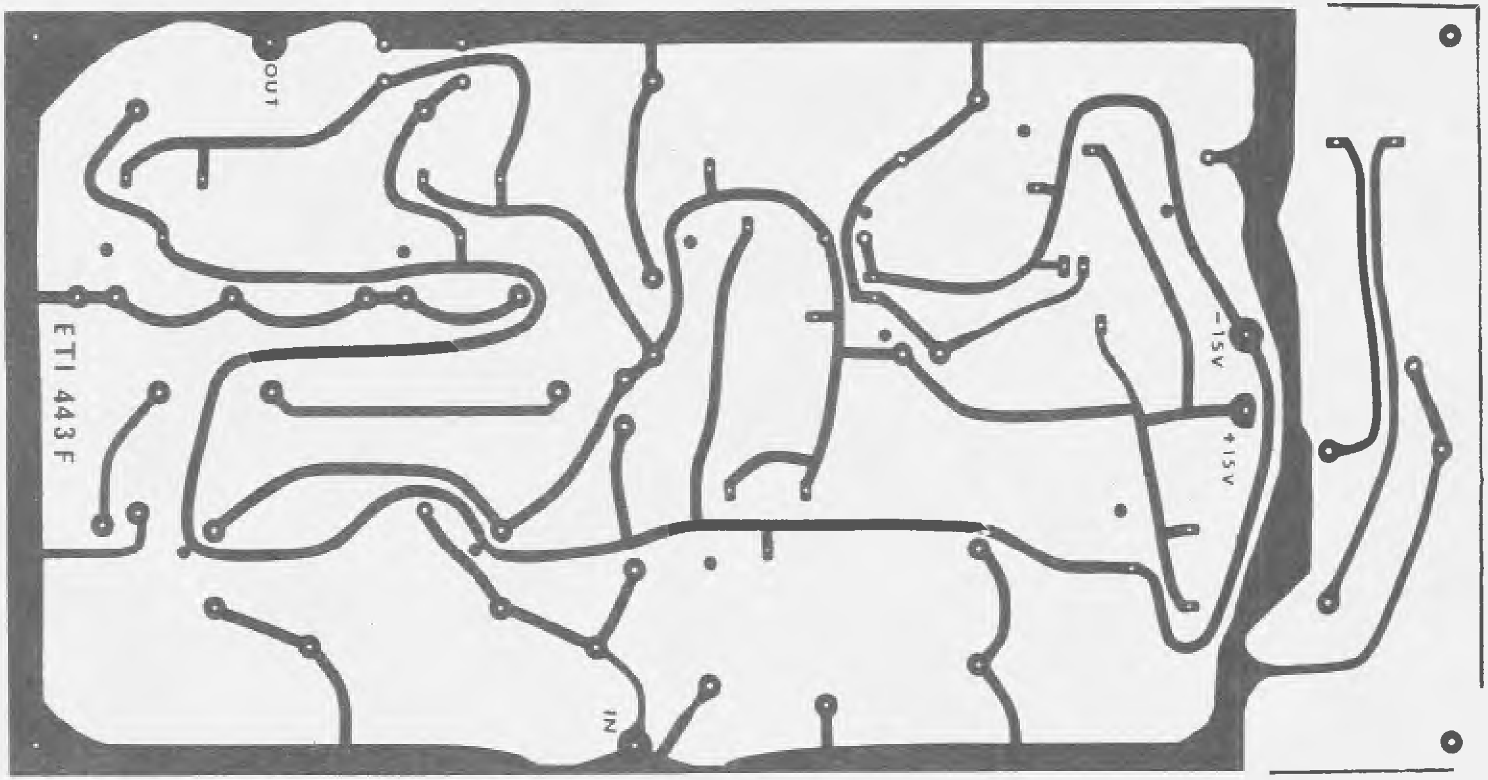


Fig. 4. Printed-Circuit layout of the component side of the board.

PARTS LIST — ETI 443

Resistors

R1-2	— 15k	½ watt	5%
R3	— 5k6	"	"
R4	— 47 ohm	"	"
R5-6	— 22 k	"	"
R7-8	— 10 k	"	"
R9	— 22 k	"	"
R10-11	— 10 k	"	"
R12	— 4k7	"	"
R13	— 22 k	"	"
R14	— 100 k	"	"
R15	— 150 k	"	"
R16-17	— 2 k2	"	"
R18-19	— 1 M5	"	"
R20-21	— 22 k	"	"
R22	— 10 k	"	"
R23	— 820	"	"
R24	— 2 k2	"	"
R25	— 150 k	"	"
R26-27	— 1 M5	"	"
R28-29	— 2 k2	"	"
R30	— 100 k	"	"
R31-32	— 270 k	"	"
R33-36	— 1 k5	"	"
R37	— 12 k	2%	"
R38	— 1 k5	"	"
R39	— 12 k	2%	"
R40	— 27 k	"	"
R41	— 470 k	"	"
R42	— 27 k	"	"
R43	— 470 k	"	"
R44	— 12 k	2%	"
R45	— 1 k5	"	"
R46	— 12 k	"	"
R47	— 27 k	"	"
R48	— 470 k	"	"
R49	— 27 k	2%	"
R50	— 470 k	"	"
R51-52	— 10 k	"	"
R53	— 22 k	"	"
R54	— 15 k	"	"
R55-56	— 10 k	2%	"
R57	— 22 k	"	"
R58	— 100	"	"
R59-60	— 10 k	"	"
R61	— 22 k	"	"
R62	— 15 k	"	"
R63-64	— 10 k	"	"
R65	— 22 k	"	"
R66-67	— 10 ohm	5%	"

*The 2% resistors may be selected from 5% valves.

Resistor Summary

2 x 10Ω, 1 x 47Ω, 1 x 820, 6 x 1.5 k, 5 x 2.2 k, 1 x 4.7 k, 1 x 5.6 k, 13 x 10 k, 4 x 12 k, 4 x 15 k, 10 x 22 k, 4 x 27 k, 2 x 100 k, 2 x 150 k, 2 x 270 k, 4 x 470 k, 4 x 1.5 M

Variable Resistors

RV 1	— 2 k trim
RV 2	— 5 k wire wound rotary
RV 3-4	— 10 k trim

Capacitors

C1-2	— 4.7μF 25 V tantalum
C3-4	— 10μF 25 V tantalum
C5	— 4.7μF 25 V "
C6-7	— 330 pF
C8	— 22 pF
C9-10	— 150 pF
C11	— 22 pF
C12	— 33 pF
C13-14	— 0.47μF polyester
C15-16	— 470μF 25 V electro
C17-18	— 0.01μF polyester
C19-20	— 1μF 25 V tantalum
C21-24	— 10μF 35 V "

Dual Transistors

TP1-TP4 LM114, 2N2920A, 2N3424

Integrated Circuits

IC1-2-7-8	— LM 747
IC3	— LM 308
IC4-5-6	— LM 301
IC9	— MC 1468L, SG 4501N, XR 1568

Diodes

D1-D4	— IN 914 or similar
D5-D8	— EM 401 or similar

Zener Diodes

ZD1-ZD2	— 12 V 400 mW
ZD3 - ZD4	— 22 V 1 W

Miscellaneous

240V/36V CT PF 3787
PC Board ETI 443
4 RCA sockets
Power cord and plug
Four 6 mm spacers
Chassis and cover 200 x 63 x 125 mm
Front Panel
Knob

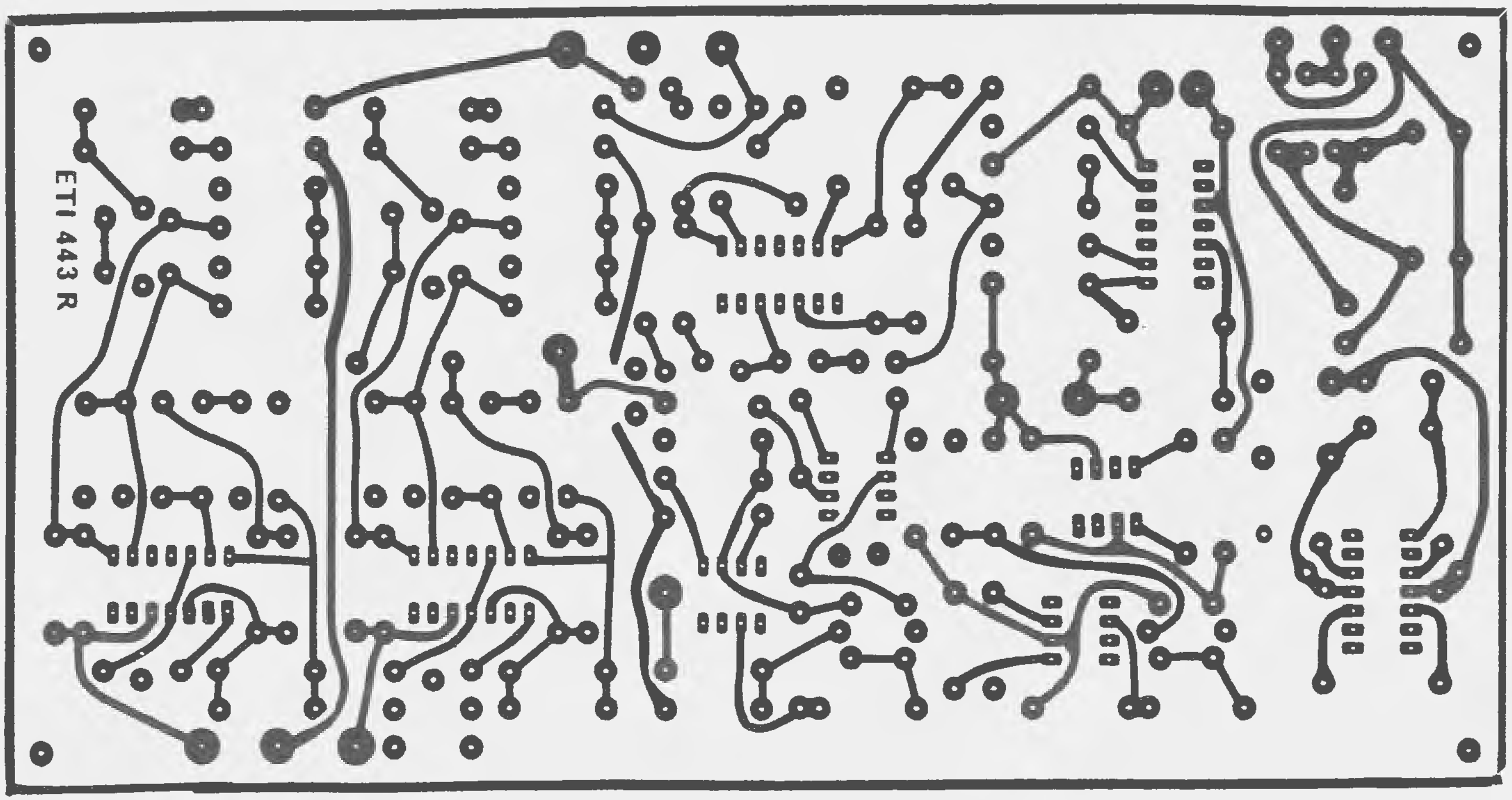
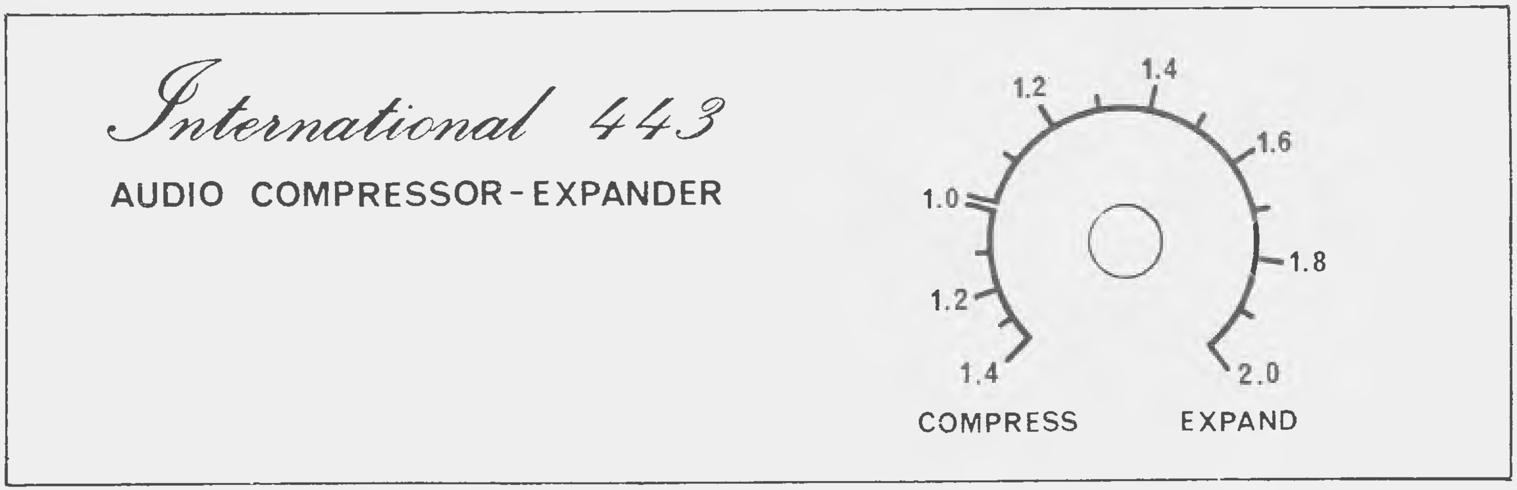
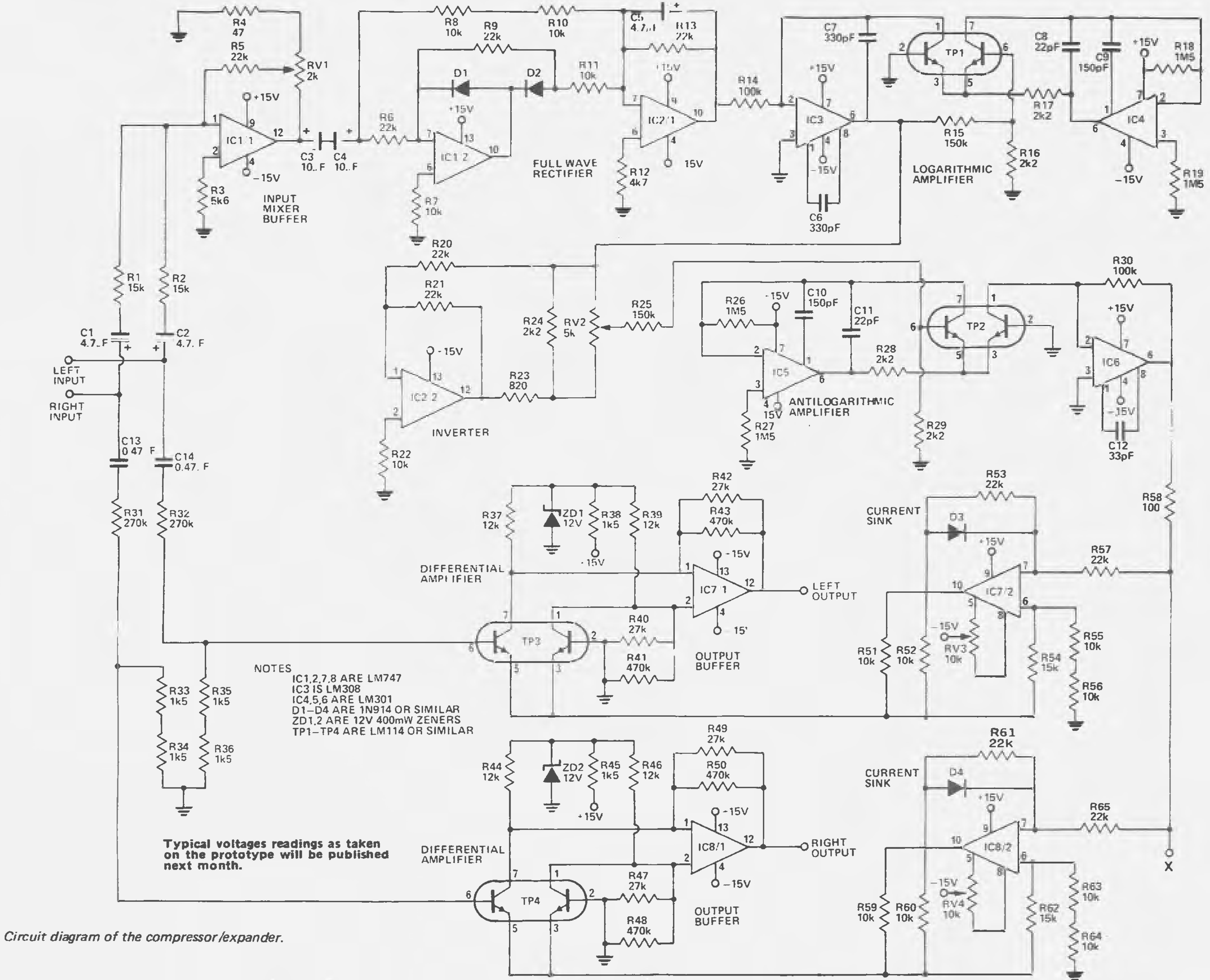


Fig. 5. Printed-Circuit layout of the non-component side.



Front panel layout shown full-size.

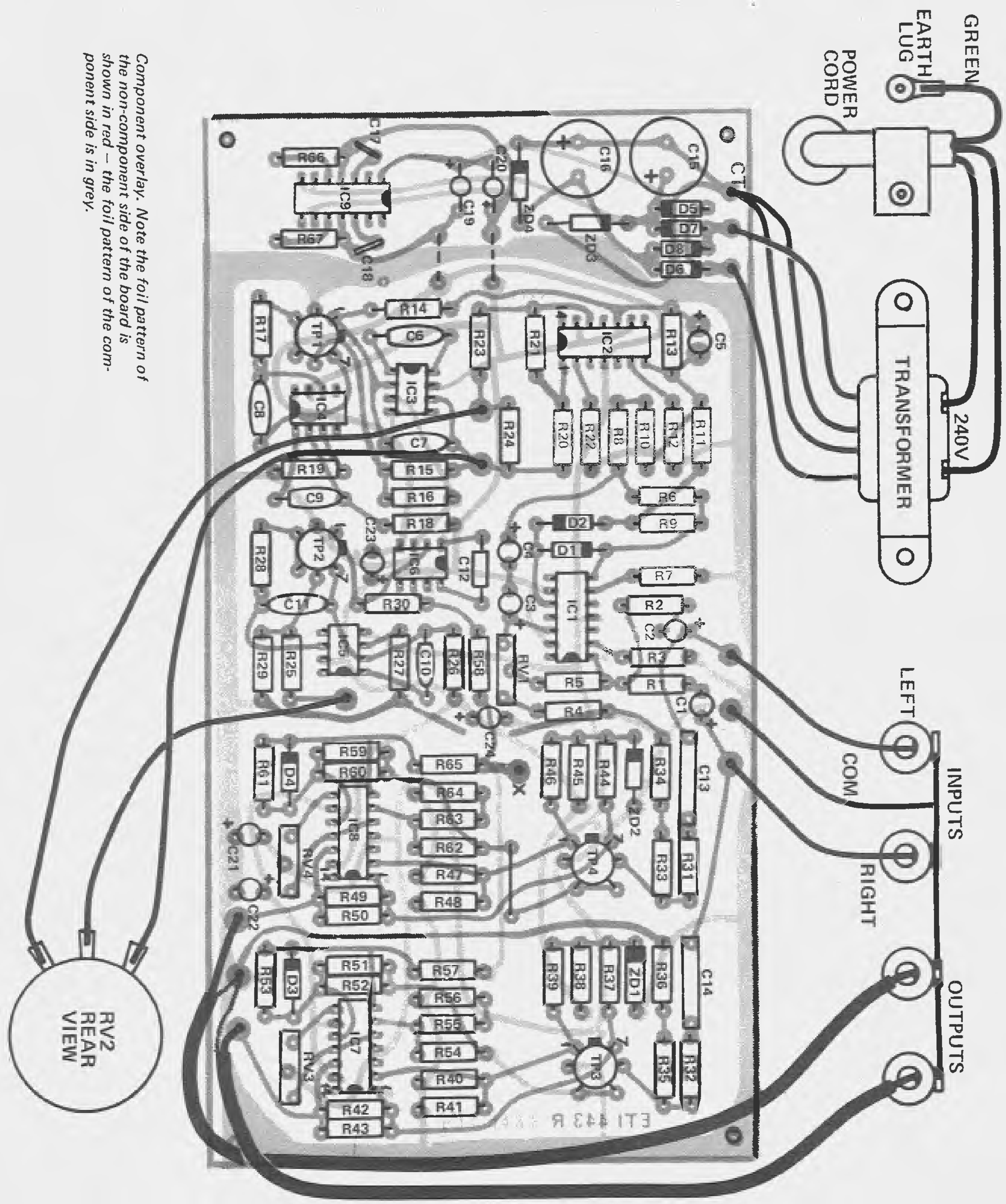
Audio expander compressor



NOTES
IC1,2,7,8 ARE LM747
IC3 IS LM308
IC4,5,6 ARE LM301
D1–D4 ARE 1N914 OR SIMILAR
ZD1,2 ARE 12V 400mW ZENERS
TP1–TP4 ARE LM114 OR SIMILAR

Typical voltages readings as taken on the prototype will be published next month.

Circuit diagram of the compressor/expander.



Component overlay. Note the foil pattern of the non-component side of the board is shown in red – the foil pattern of the component side is in grey.

HOW IT WORKS – ETI 443

The heart of an audio compressor-expander is invariably a voltage controlled amplifier; that is, an amplifier whose gain is set by means of an applied dc voltage. This dc voltage itself must be derived from the amplitude of the audio input signal, averaged over some preset period, and modified to give the required compression or expansion characteristics. In the circuit of Fig. 1, each portion of the circuit is identified according to its function. These portions, in turn, are grouped into three main sections; an ac to dc converter, a power function generator, and a stereo analogue multiplier.

The two channels of stereo input are mixed in buffer amplifier 1C1/1, and the gain of this stage is set so that an output of about 1 volt is given by a signal which corresponds to moderate loudness. Amplifiers 1C1/2 and 1C2/1 are used to obtain precision full-wave rectification of the mixed input, and the resulting positive dc voltage is stored in capacitor C5. The choice of value for C5 is important, and it will be discussed in detail later on.

Amplifiers IC3 and IC4 together with the transistor pair TP1 constitute a logarithmic amplifier. With the components shown, the behaviour of this amplifier is described by the equation:

$E_{out} = -4.15 \log E_{in}$

The inverse of E_{out} is obtained from amplifier 1C2/2 and by connecting the compression-expansion control potentiometer as shown between the input and output of this stage, any voltage between E_{out} and $-0.3E_{out}$ can be obtained. 1C5, 1C6 and TP_2 are combined as an antilogarithmic amplifier (or exponential), which is the exact inverse of the logarithmic amplifier so that the effect of all these operations on the input signal is to give a positive dc output voltage, equal in magnitude to the input voltage raised to the power k, where k can have any value from –0.3 to 1.

In the analogue multiplier sections, this voltage (E_{in}^{k}) is converted to current by amplifiers 1C7/2 and 1C8/2, thus setting the effective gain of the differential amplifiers TP_3 and TP_4. These are directly coupled into the output buffers 1C7/1 and 1C8/1, so that the stereo signals reaching the outputs have been amplified by a factor which depends on the average amplitude of the signals, and the compression-expansion control setting. The actual voltage gain can vary from 0.0004 to 14, which represents a power gain range of 97 dB.

50 - 100 WATT AMPLIFIER MODULES

This is our very reliable 422 amplifier redesigned for simplicity in construction.

THE MOST POPULAR AMPLIFIERS we have ever published are the 100 W guitar amplifier (ETI 413) and the 50 W stereo amplifier (ETI 422). These amplifiers have proved very reliable for the many hundreds of readers who have built them.

Both of the amplifiers are, however, a bit fiddly to build (as are most power amplifiers) because the power transistors must be mounted on a heat sink which therefore needs wiring to the control board. Whilst this module has the same electrical design as the 422 the layout has been greatly simplified.

The new design was originally a replacement amplifier for the 422. We hope to publish the complete details next month. We soon realised that by adding two transistors we had a replacement for the 100 watt amplifier as well.

Both versions are very easy to build and set up with all the components, including the power transistors, on the pc board (eliminating another source of possible errors).

Construction

Assemble the module, less the heatsink components, with the aid of the overlay in Fig. 5. Now mount the heatsink bracket on the component side of the board with two 6 BA screws making sure the other holes line up with those in the pc board.

Mount the power transistors and the BD139/140 using insulating washers and silicon grease. If the amplifier is to be run continuously at full power we recommend you use beryllium oxide washers rather than mica ones. This will lower the junction temperature about $10^{\circ}C$.

SPECIFICATION*	ETI 480	
	50 W version	100 W version
Output power	50 W into 8 ohms	100 W into 4 ohms
Frequency response	5 Hz – 50 kHz	5 Hz – 50 kHz
at rated power	$^{+0}_{-3}$ dB	$^{+0}_{-3}$ dB
Input Sensitivity	500 mV	1 V
Distortion	see Fig. 1	
Signal to noise ratio	100 dB	100 dB
Protection	1.5 A fuses	3 A fuses
Damping Factor	25	20
Power Requirement	33 V @ 1.2 A	33 V @ 2.4 A

** Measured performance of prototype*

The screws holding the 2N3055/MJ 2955 should also be insulated where they pass through the heatsink bracket. The BD 139 and BD 140 do not need any insulation other than the mica, provided 6 BA (or 3 mm) screws are used. In the 100 W version the addition transistors are mounted on the heatsink bracket outside the pc board area.

The heat sensing transistor Q6 should be inserted into the bracket using silicon grease, bend the lead flat against the pc board and solder to the pads provided When installed, the transistor should be in the centre of the heatsink.

The recommended power supply is shown in Fig. 3. This supply gives about 40 V on no load, dropping to about 32 V on full output. This allows reproduction of transients beyond 50 W (or 100 W) whilst providing a degree of protection for the output transistors. If a regulated supply is used it should not be higher than ± 35 V.

If no preamp is to be used, a couple of chassis-mounting capacitors (4700 μF) with the diodes wired across the terminals will suffice. If the pc board is used there is facility for building the preamplifier regulator and fitting a dethump relay (if required). The power amplifier itself does not produce any thump.

Alignment

The only adjustment you have to make is to set the current using RV1. The bias current for the 50 W version should be 20–25 mA and for the 100 W version it should be 30–35 mA. The figures are for the amplifier running cold. These currents increase about 50% when the amp gets hot.

To measure the current we recommend soldering a 100 ohm ½ W resistor across each fuse holder and removing the fuses. With no load connected and no input adjust RV1 until there is about 2.5 V (3.5 V for 100 W version) across the resistors. There may be a slight voltage difference between the two resistors, so just take an average. It's not that critical. This method of measuring current is much easier on your testmeter should there be a fault in the amplifier.

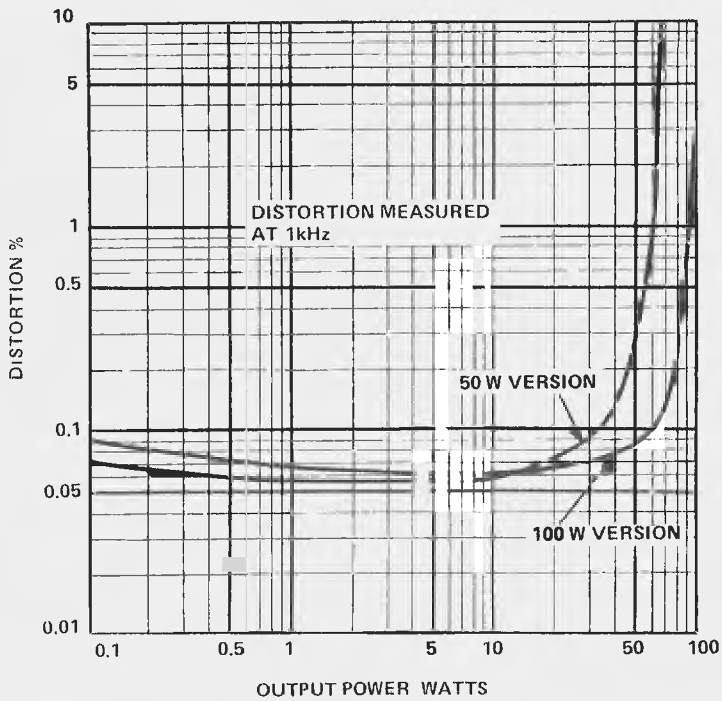
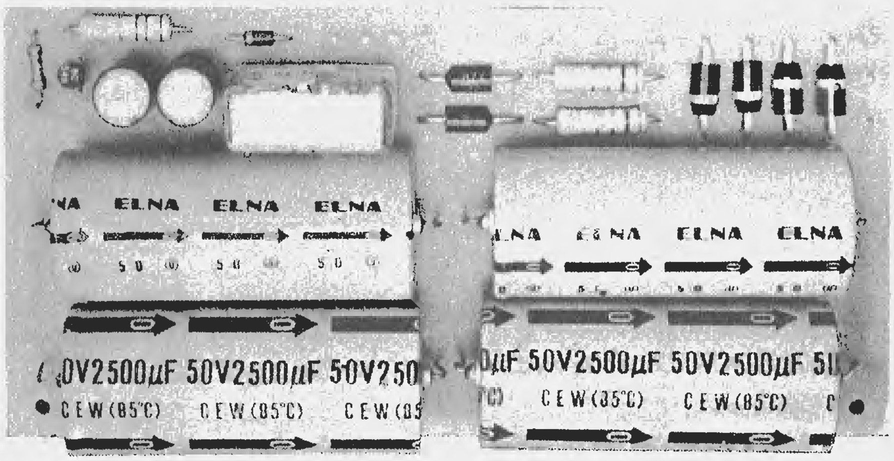


Fig. 1. Graph showing relationship between output power and distortion.



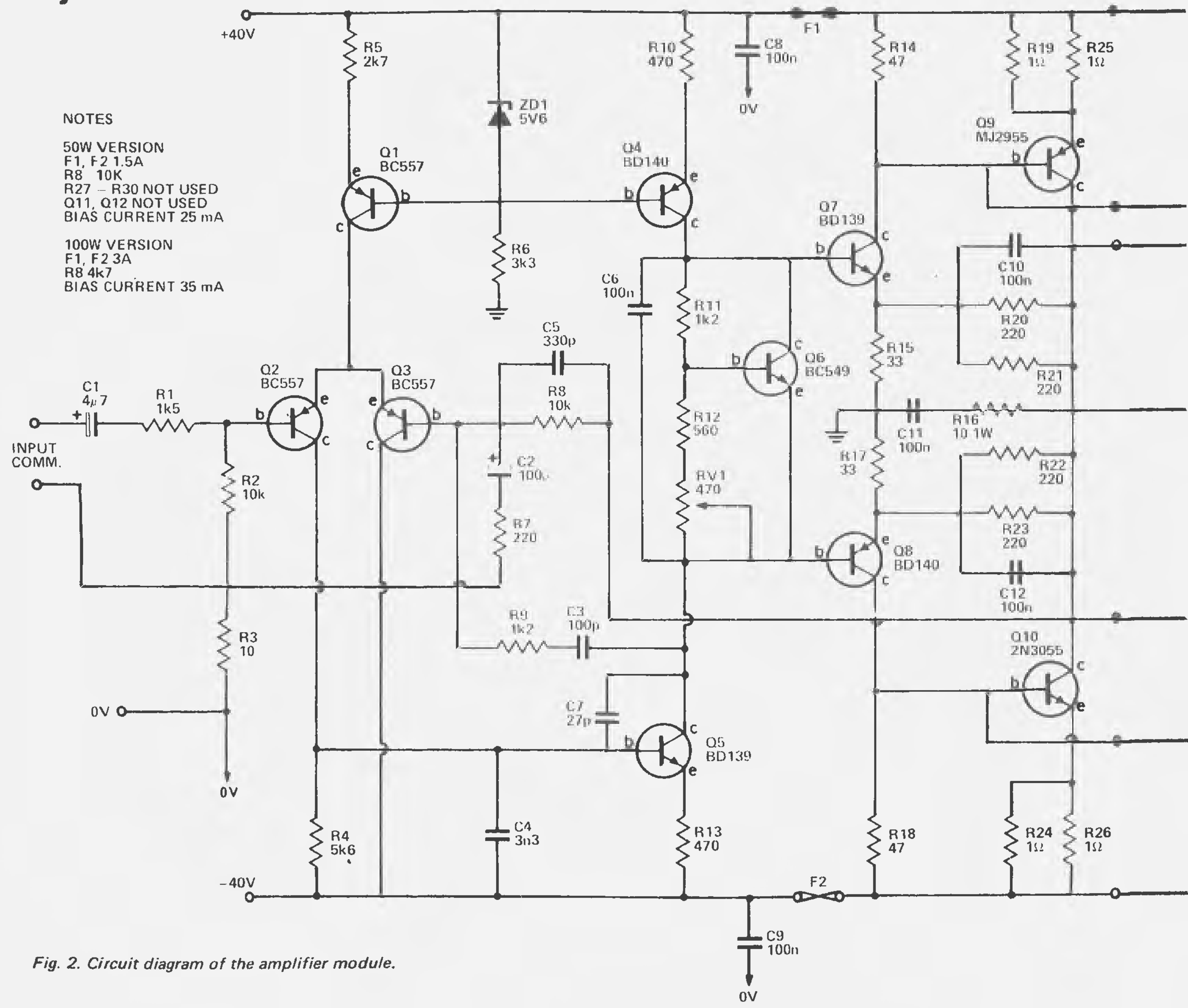


Fig. 2. Circuit diagram of the amplifier module.

How it Works ETI 480

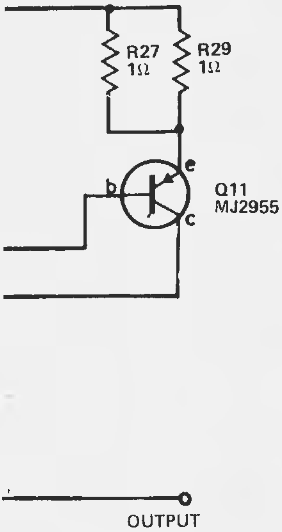
The input signal is fed via C1 and R1 to the base of Q2 which, with Q3, forms a differential pair. Transistor Q1 is a constant-current source supplying about 2 mA. This current is shared by Q2 and Q3. Transistor Q4 is also a constant-current source supplying about 10 mA which, if no input signal exists, flows through Q5 and Q6. The differential pair controls Q5 and thus the voltage at its collector.

The resistors R11 and R12 together with potentiometer RV1; control the voltage across Q6 and maintains it at about 1.9 V. But as Q6 is mounted on the heatsink, this voltage will vary with heatsink temperature. Assuming that the voltage on the bases of Q7 and Q8 is equally spaced about zero volts (i.e., 0.95 volts) the current will be set at about 12 mA through Q7 and Q8. The voltage drop across the 47 ohm resistors (R14, R18) will be enough to bias the output transistors Q9 and Q10, on slightly to give about 10 mA quiescent current in these transistors. This quiescent current is adjustable by means of potentiometer RV1.

Local feedback is applied to the output stage by the network R20–R23, giving the output stage a voltage gain of about four. The overall feedback resistor, R8, gives the required gain control.

Protection to the amplifier (against shorted output leads) is provided by fuses in the positive and negative supply rails to both amplifiers.

Temperature stability is attained by mounting Q6 on the heatsink and this transistor automatically



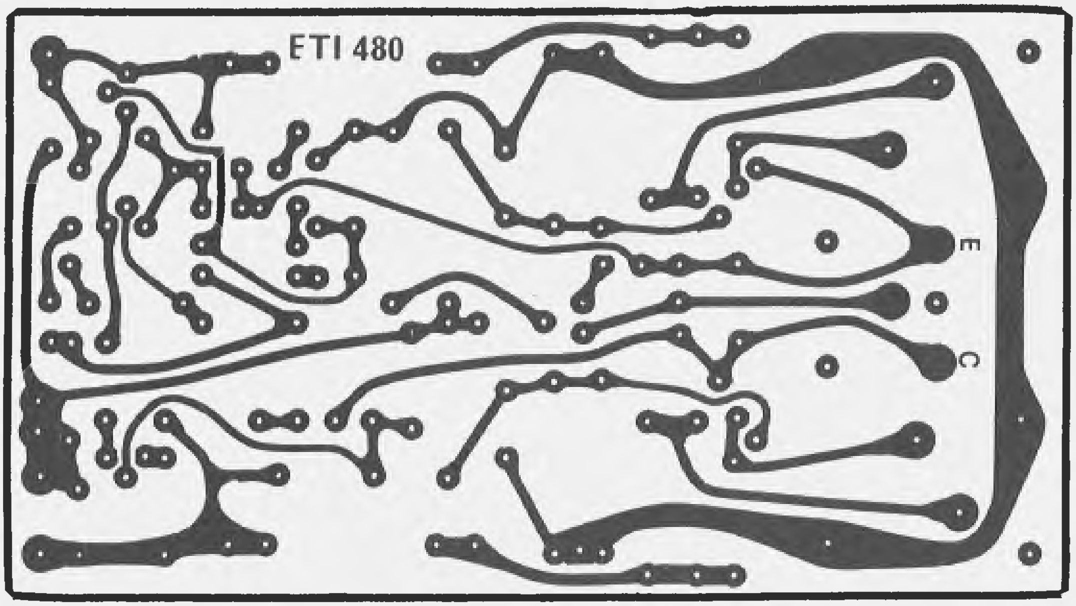


Fig. 4. Printed circuit layout of the amplifier. Full size 140mm x 76mm.

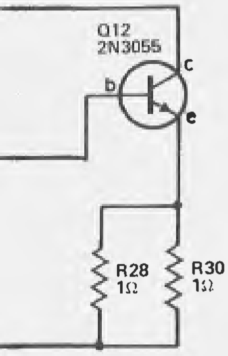
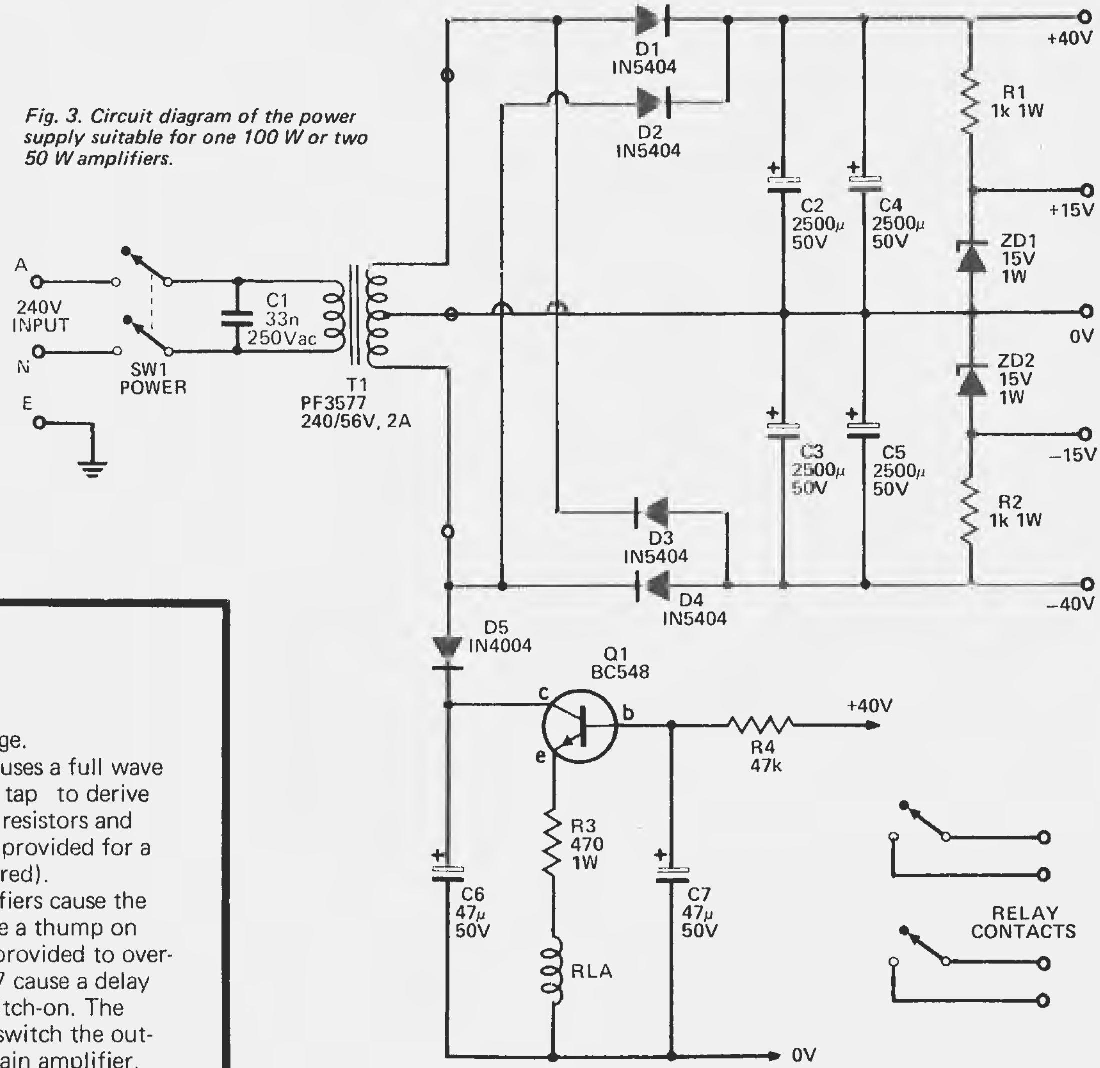


Fig. 3. Circuit diagram of the power supply suitable for one 100 W or two 50 W amplifiers.



adjusts the bias voltage.

The power supply uses a full wave rectifier and a centre tap to derive ±40 V dc. Dropping resistors and zener diodes are also provided for a preamplifier (if required).

As some preamplifiers cause the main amplifier to give a thump on switch-on, a relay is provided to overcome this. R4 and C7 cause a delay of about 3 sec on switch-on. The relay can be used to switch the output leads from the main amplifier.

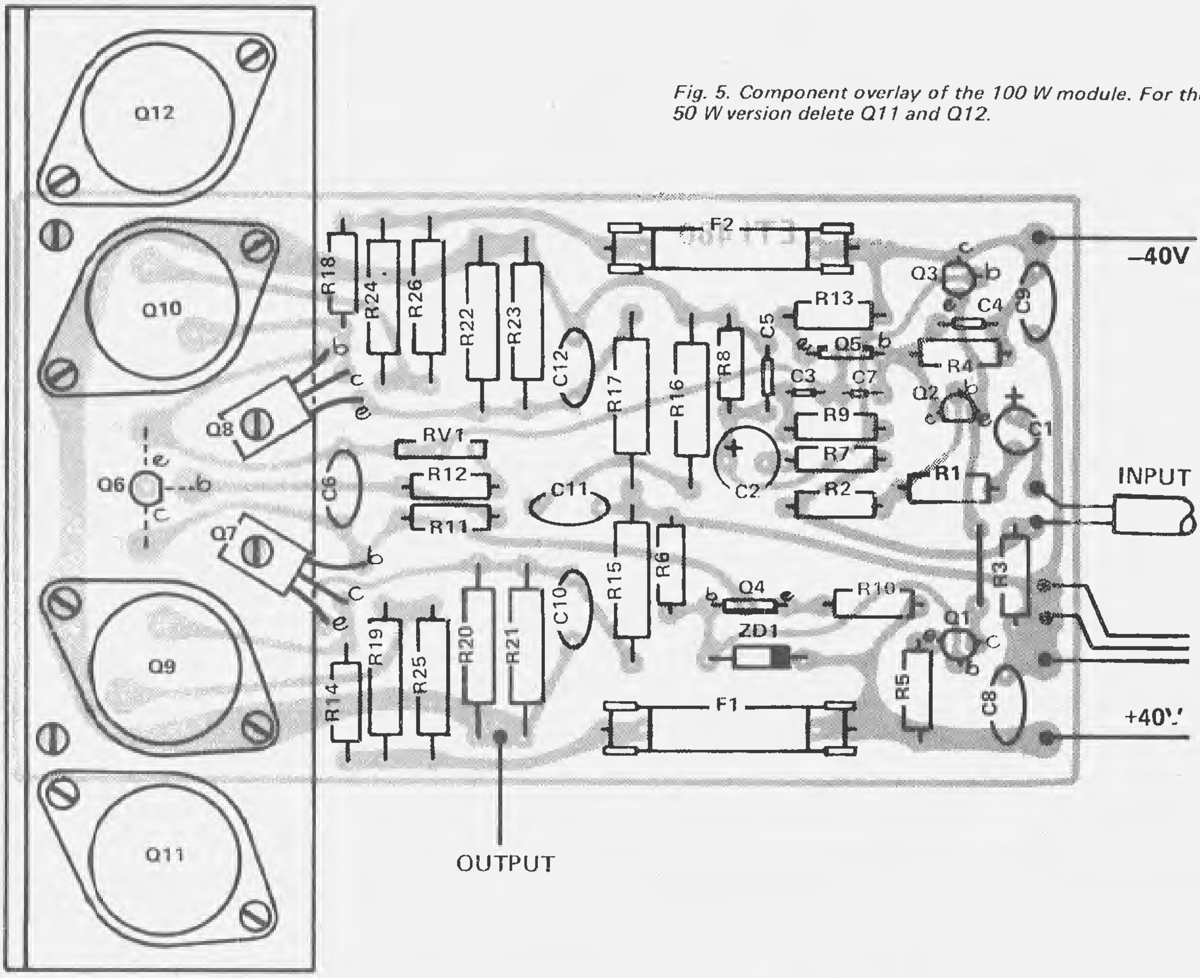


Fig. 5. Component overlay of the 100 W module. For the 50 W version delete Q11 and Q12.

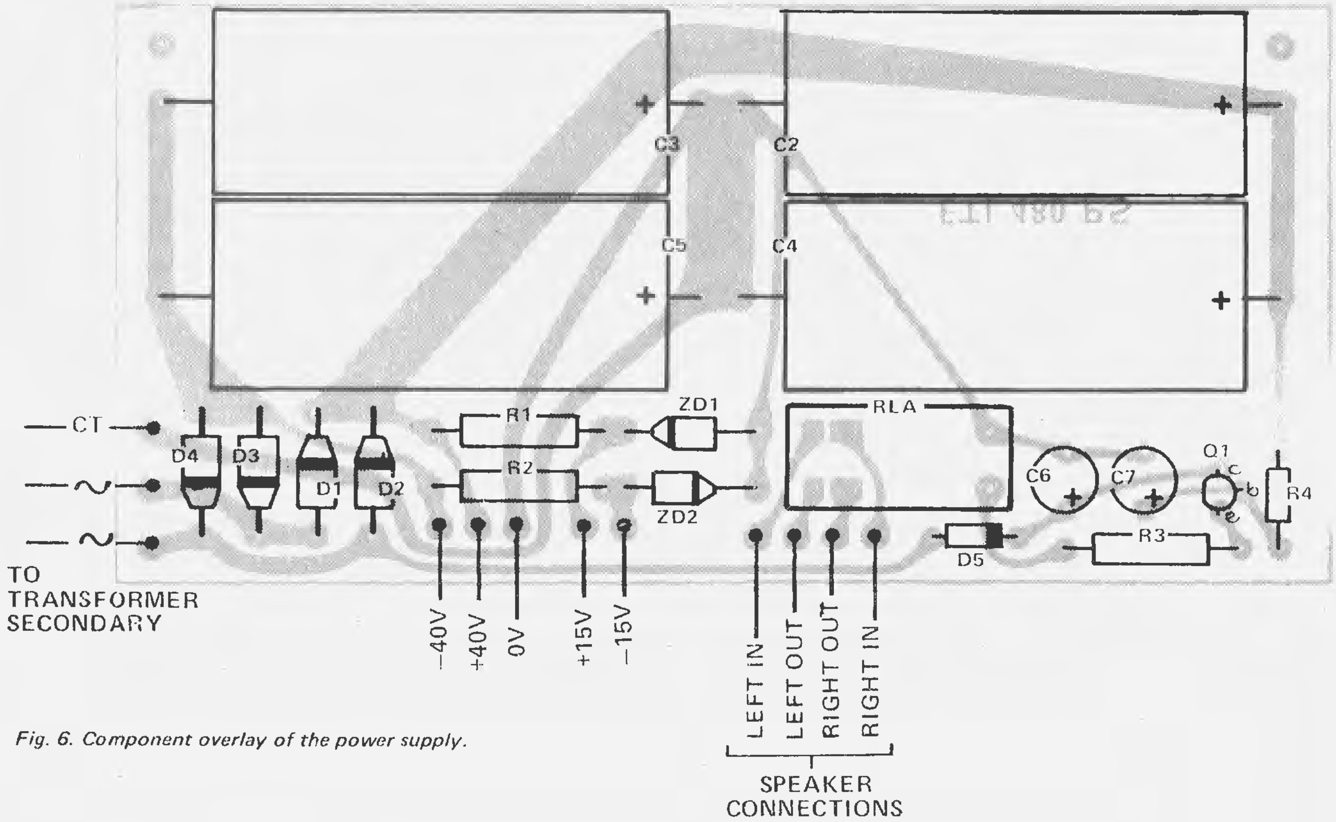


Fig. 6. Component overlay of the power supply.

PARTS LIST – ETI 480

Resistors	*all ½ W 5% unless noted*
R1	1k5 ½ W 5%
R2	10 k
R3	10
R4	5k6
R5	2k7
R6	3k3
R7	220
R8*	10 k
R9	1k2
R10	470
R11	1k2
R12	560
R13	470
R14	47
R15	33 1 W
R16	10 1 W
R17	33 1 W
R18	47 ½ W
R19	1 Ω 1 W
R20–R23	220 1 W
R24–R26	1 Ω 1 W
R27 R30*	

Potentiometer

RV1	470 trim type

Capacitors

C1	4 µ7 25 V electro
C2	100 µ 16 V electro
C3	100 p ceramic
C4	3n3 polyester
C5	330 p ceramic
C6	100 n polyester
C7	27 p ceramic
C8–C12	100 n polyester

Transistors

Q1–Q3	BC557
Q4	BD140
Q5	BD139
Q6	BC549
Q7	BD139
Q8	BD140
Q9	MJ2955
Q10	2N3055
Q11*	
Q12*	

Zener diode

ZD1	5.6 V 400 mW

Miscellaneous

PC board ETI 480
Four PC mounting fuse clips (FC1)
Two fuses 1.5 A*
Heatsink bracket to Fig. 9 *
Insulation kits for Q7–Q12.

*** For 100 W version**
R8 is 4k7 ½ W
R27–R30 are 1 Ω 1 W
Q11 is MJ2955
Q12 is 2N3055
Fuses are 3A
Bracket is to Fig. 8.

PARTS LIST – ETI 480 PS

Resistors

R1, 2	1 k	1 W	5%
R3	470	1 W	5%
R4	47 k	½ W	5%

Capacitors

C1	33 n 250 V ac
C2–C5	2500 µF 50 V electro
C6, 7	47 µF 50 V electro

Diodes

D1-D4	1N5404
D5	1N4004

Transistor

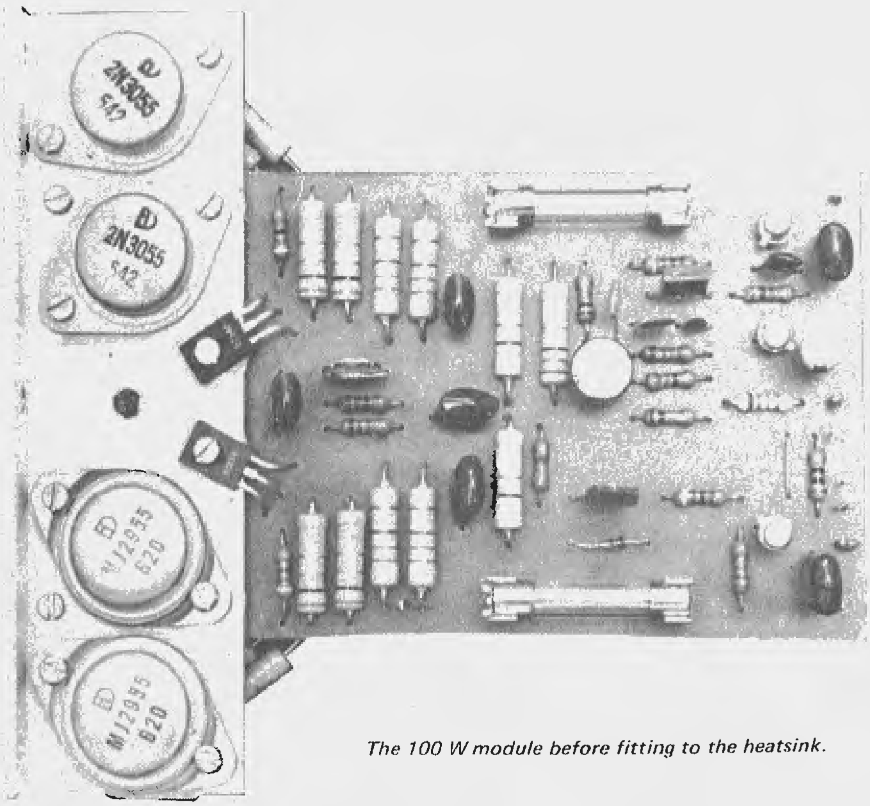
Q1	BC 548

Zener diodes

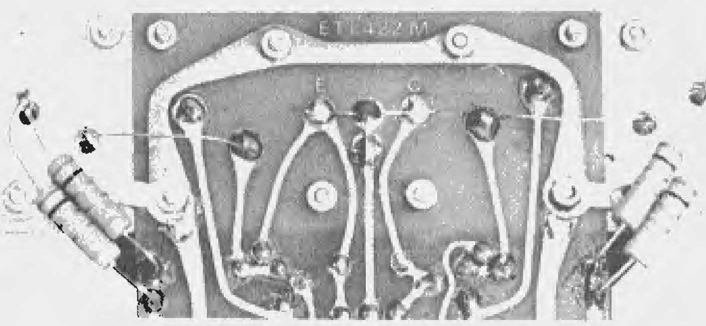
ZD1, 2	15 V 1 W

Miscellaneous

PC board – ETI 480 PS
Relay 2 pole 280 ohm coil
Transformer PF3577 or similar



The 100 W module before fitting to the heatsink.



Rear view of the 100 W module showing the links and resistor which are external to the pc board.

(Continued on page 61)

Project 482

STEREO AMPLIFIER

This amplifier is a redesign of our successful International 422 project incorporating modular construction, filters, and ultra-modern CMOS switching.

UNLESS THERE IS A GOOD REASON, we don't like to redesign an existing project just for the sake of it. The ETI 422 amplifier, which we designed back in May '74, has been very popular, but we would be the first to admit that construction is not easy (especially in the wiring of the heatsinks).

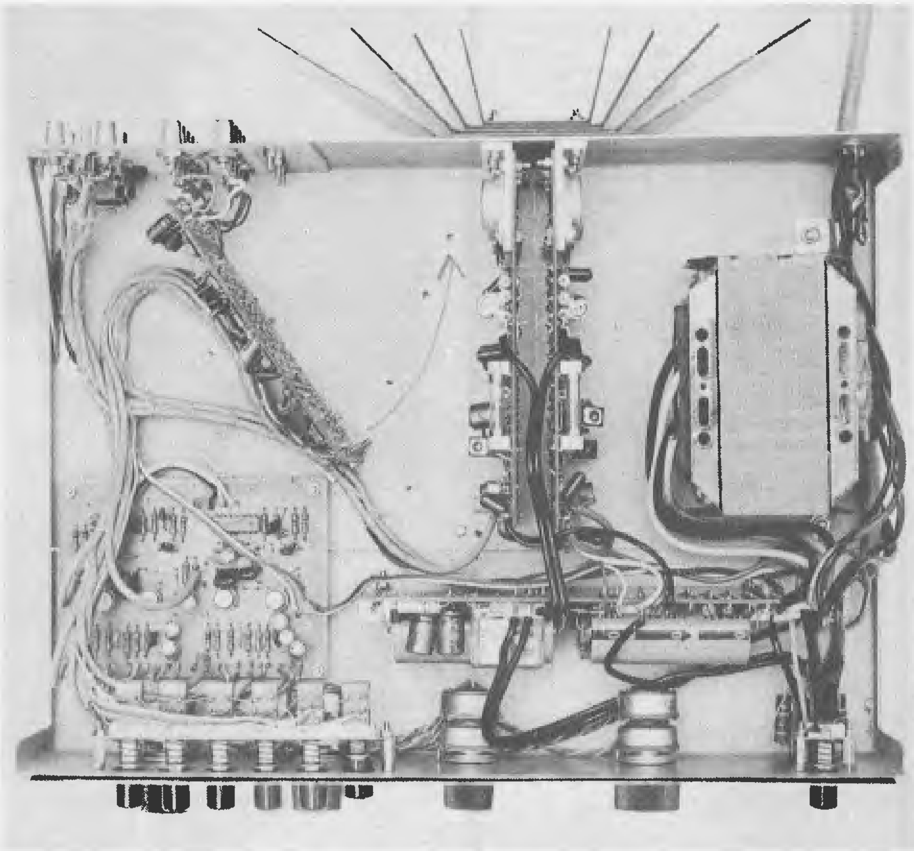
We have now pre-empted this project with our design for the ETI 480 50W and 100 W power modules — in which the construction and wiring is very easy. The modules were based on the original 422 power amplifier design.

To use these modules in the 422 would mean at least new metalwork and a new internal layout. We therefore decided to go a little further and add a rumble and scratch filter and something new in audio amplifiers, at least in magazine projects, in solid-state switching of the audio inputs and filters. This simplifies wiring even more as the only wires connected to the selector switch are control wires — not shielded cable as before.

Construction

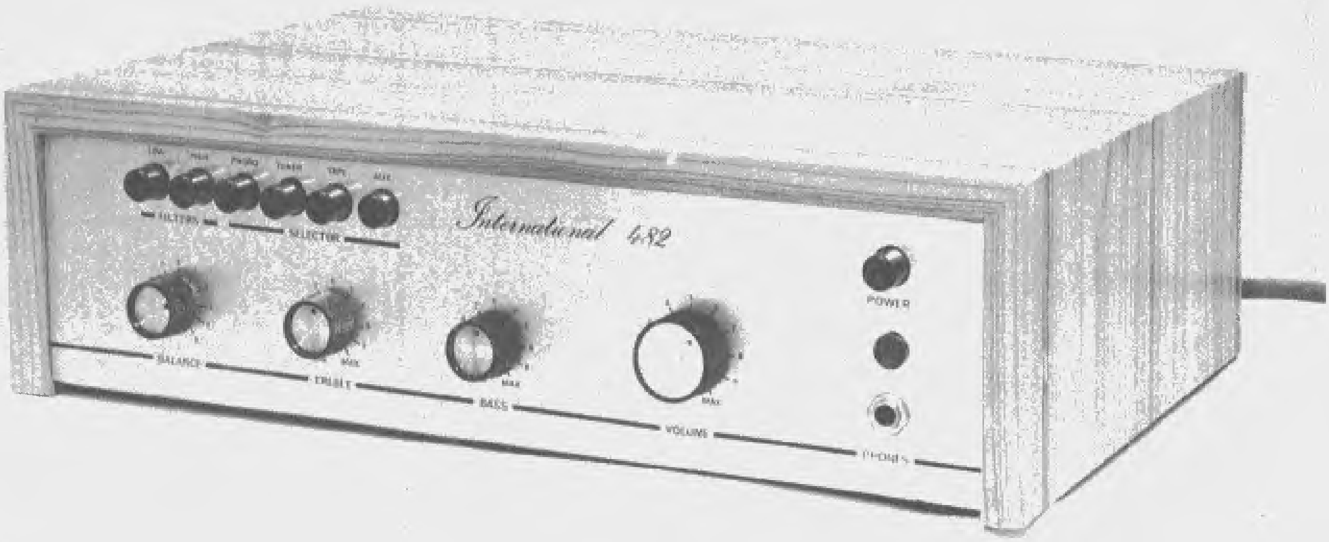
Construction details of the power amplifier and power supply boards were described in the last article.

The preamplifier is built on two boards, one being the 'mag' preamp and selector board; the other being the tone control and filter board. These can be assembled with the aid of the appropriate overlay drawing. Note that the



Internal view showing preamp board pivoted forward to allow access to the rear

mag preamp board has tracks on both sides and must be soldered on both sides where applicable. If you use a small soldering iron and fine solder, this should not prove any problem. Use pc board pins for all external wires as this



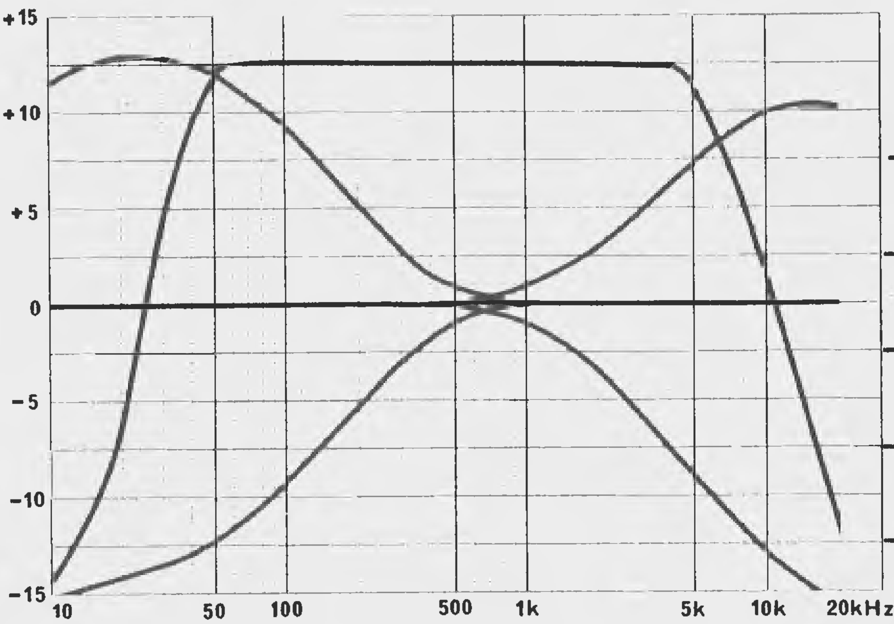
SPECIFICATION ETI 482

Output power	**50 watts into 8 ohms**
Frequency response 20Hz–20kHz	**± 0.5 dB**
Signal to noise ratio with 50 W output	
Tape, tuner and aux inputs	**–79 dB**
Disc input (re 10mV)	**–63 dB**
Input sensitivity	
Tuner and aux inputs	**180 mV into 100k**
Tape input	**180 mV into 47k**
Disc input	**2.5 mV into 47k**
Main amp input	**500 mV into 10k**
Total harmanic distortion at 1 kHz	
50 watts out	**0.3%**
10 watts out	**0.08%**
1 watt out	**0.08%**
Tone controls	**see graph**
Filters	**see graph**
Damping factor	**25**
Channel separation	**45 dB**

makes wiring much easier later.

Commence assembly of the chassis with the 12mm spacers for the selector switches and the power switch. Although the switches should not be fitted yet, the countersunk screws used to mount them are covered by the front panel and these will not be accessible later. The potentiometer and tone control board can now be installed and interconnected. The small rear panel can be assembled and fixed to the chassis.

Add wires about 40 mm long to each of the 10 inputs to the mag preamp board (it is neater if these are soldered to the rear of the board) and connect them to the appropriate RCA sockets. Also add an earth link from this board to a lug under one of the phono input sockets. Connection of all the commons of the RCA inputs is done on the panel itself (if you follow our construction method). The mag preamp board can now be installed.



Graph showing frequency response of tone controls and filters

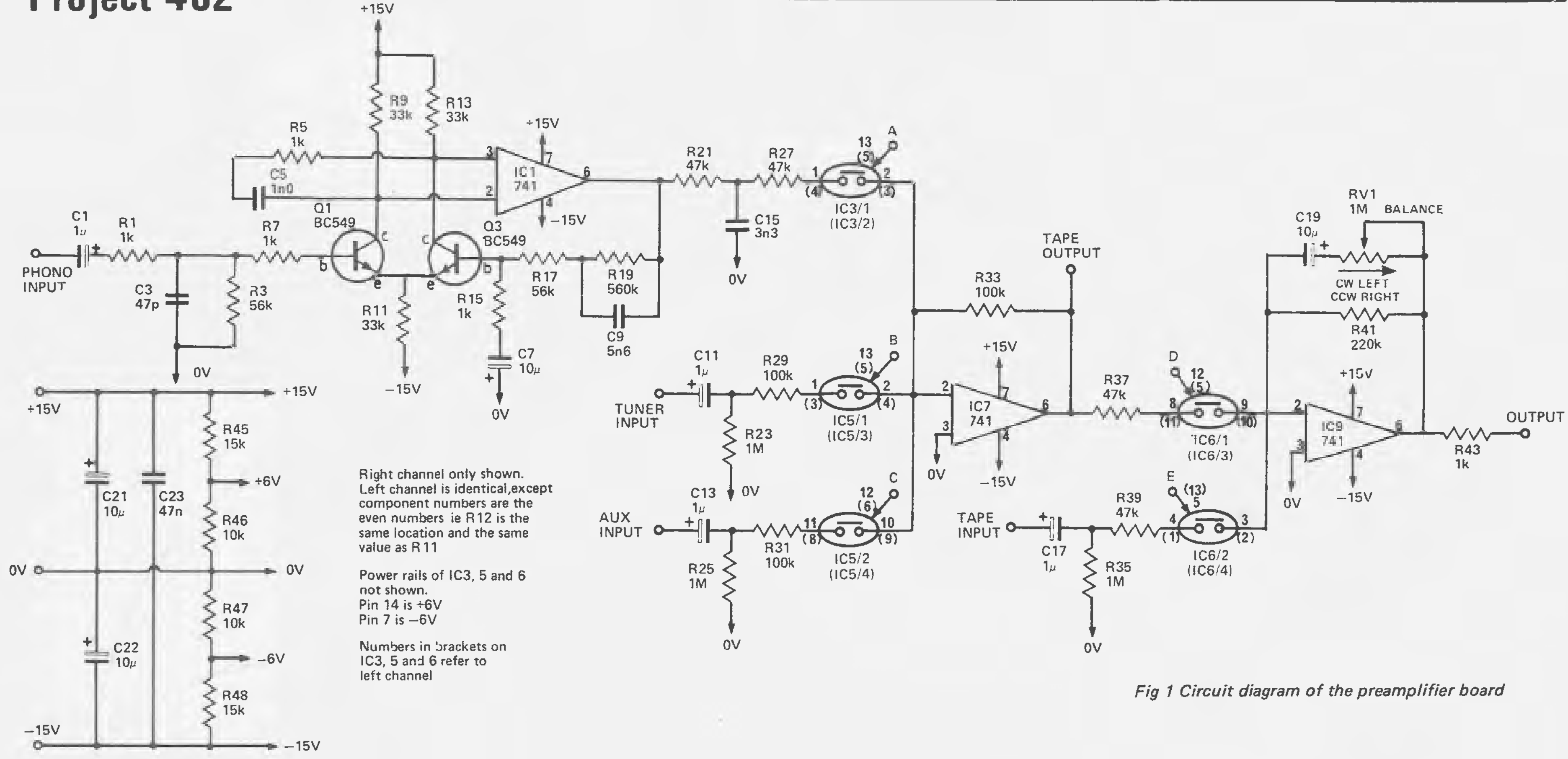


Fig 1 Circuit diagram of the preamplifier board

How it Works — ETI 482

The output from a magnetic pickup has to be amplified and equalised before it can be used. This is achieved using Q1, 3 and IC1 to provide a gain of about 40 dB at 1 kHz and using C9 and C15 to provide the equalisation required to meet the RIAA curve. The transistors are used to reduce the noise of the 741 amplifier to acceptable levels.

Selection of the inputs is done by IC3, 5 and 6, which are CMOS analogue switches. If the control input to these devices is high (+6V) the switch appears as a 300 ohm resistor and if it is low (-6V), it appears as an open circuit. Therefore, IC3/1, IC5/1 and IC5/2 can select phono, tuner or aux inputs and IC7 buffers the one selected.

The output of IC7 is used as tape output for recording purposes. The tape input is fed with a second buffer, IC9, and IC6/1 disconnects IC7 when this is to allow monitoring (when recording) and this is selected by depressing both the tape button and the input required. The gain of the second buffer, IC9, is variable by means of RV1, which is the balance control. The two channels are wired to the opposite way around on RV1, so that increasing gain on one channel decreases the gain on the other.

The filters used are two-pole active types and CMOS switches are used to enable or inhibit the circuits. C27 and C29 determining the low filter cutoff frequency and the valus can be varied to suit your requirements. The values given give a cutoff at about 50 Hz and increasing the capacitance decreases the cutoff frequency, and vice versa. In the high cut filter C31 and C33 determining the frequency and these values can also be varied if required. The approximate ratio between these capacitors should be maintained.

The tone controls are conventional and we used the same values as in the 440 amplifier (they have a better range than those in the original 422). To reduce the effective noise level, the volume control is wired between the filter section and the tone control stage. This does mean, however, that the input levels are more critical than they would be if the control was further back in the circuit. Input levels should be kept below about 2 volts.

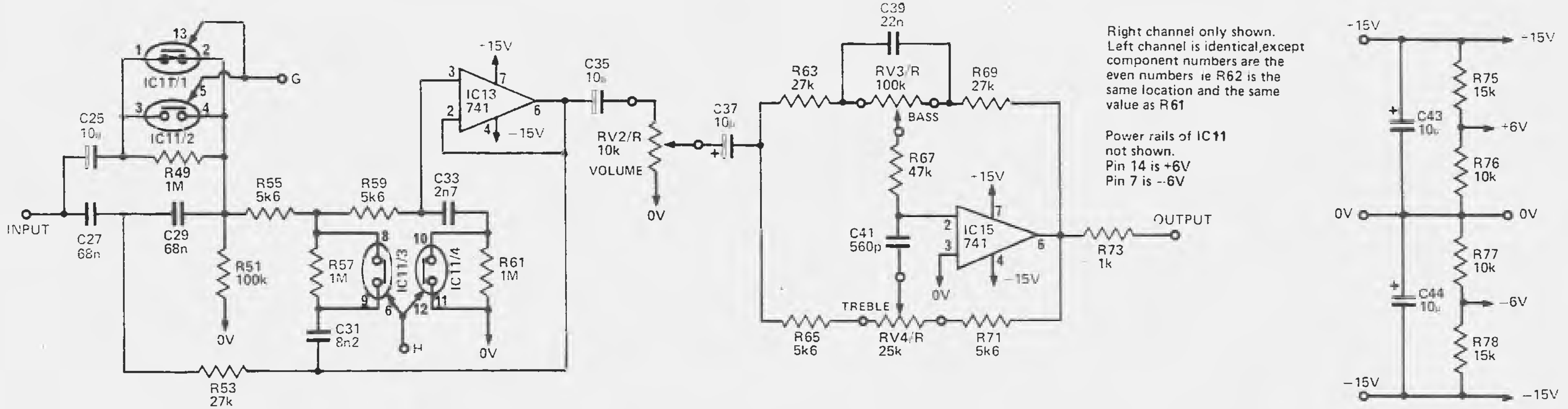


Fig 2 Circuit diagram of the filter and tone control board

Construction continued.

Before fitting the amplifier modules they should have the bias current adjusted. While this can be set later, if anything is wrong it is easier to fix before installation. Provided no load is connected, no heatsink is required at this stage. The module can now be fitted, along with the heatsink on the rear of the chassis. The chassis goes between the modules and the heatsink, but the heat loss is not great. While the heatsink described is not the only one which could be used, it must be about this size and it must be able to be clamped against the rear panel to ensure adequate cooling.

The power supply board and the selector switches can now be added and the complete amplifier wired with the aid of the diagram in Figure 4. We left the transformer out until this stage to keep the weight down. It can now be added and the wiring completed. Mechanical drawings and PCB artwork follow on the next four pages.

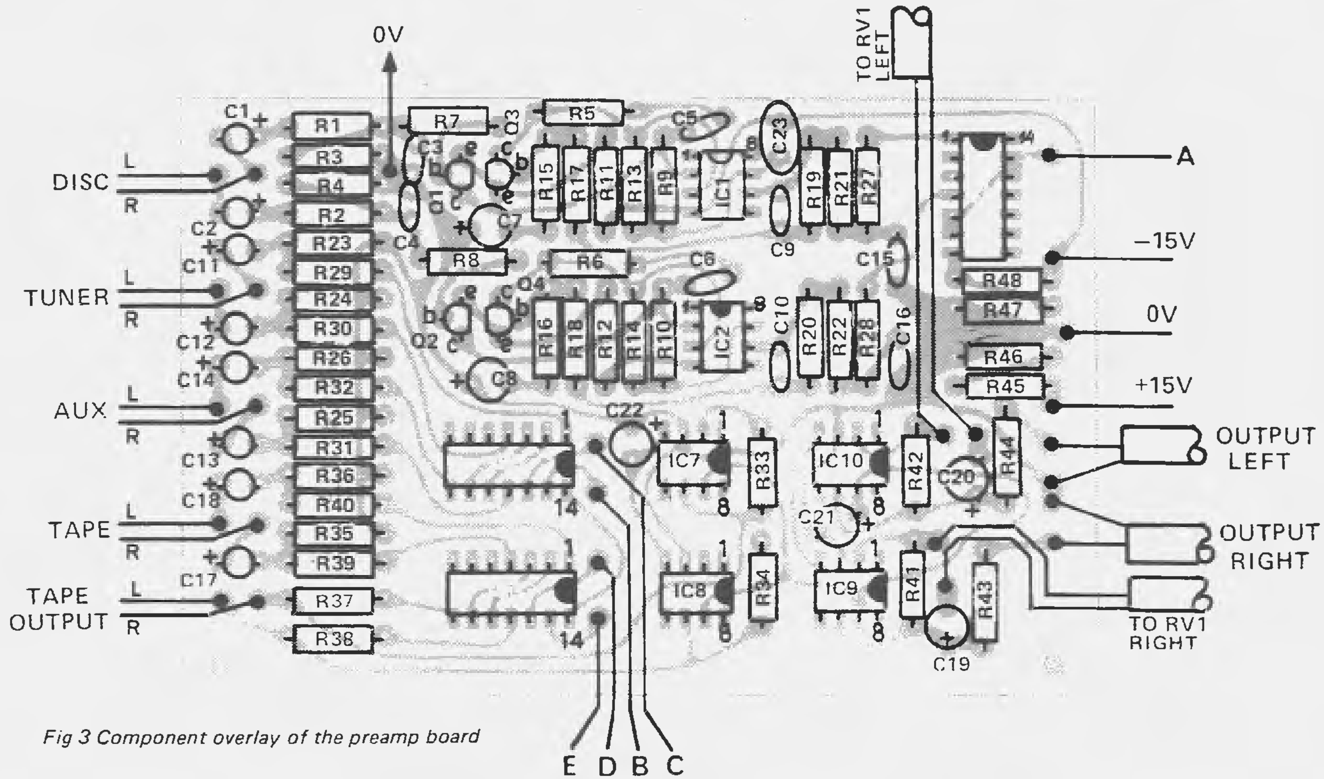


Fig 3 Component overlay of the preamp board

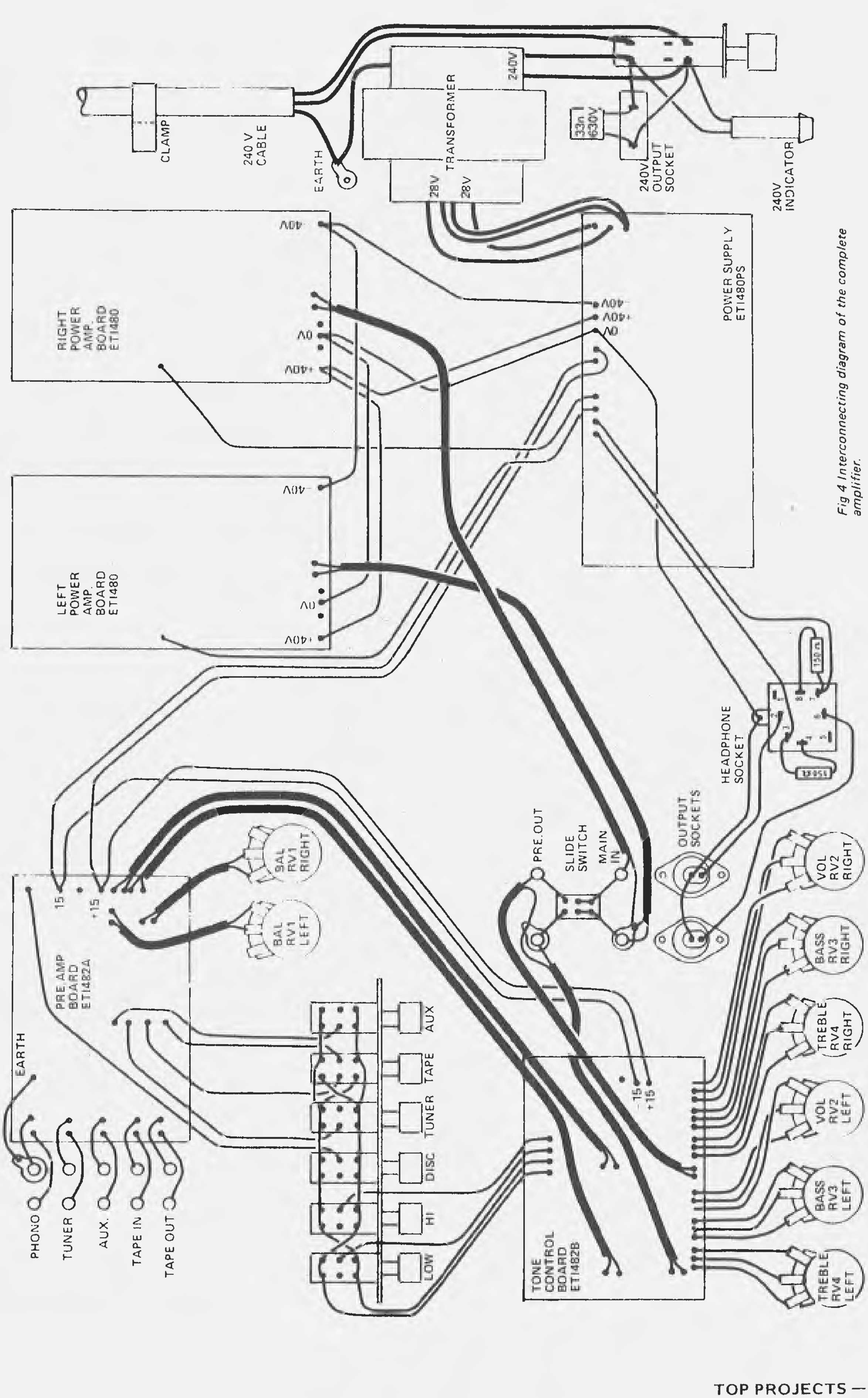


Fig 4 Interconnecting diagram of the complete amplifier.

PARTS LIST ETI 482 GENERAL

2	50 W ETI 480 Amplifier modules
1	ETI 480 P Power supply module
	chassis
	cover
	Front panel
	Heatsink
	Rear panel
5	brackets
4	knobs
1	Isostat Selector switch P/N 4313-6
1	Isostat Power switch
1	2 pin power socket
1	33 nF 630 V capacitor
1	240 V power indicator
1	Power cord, grommet and clamp
1	Stereo phone socket
14	Single RCA sockets AT 700
1	Small double pole slide switch
2	2 pin DIN socket
8	12mm spacers
	nuts, bolts, washers etc.

PARTS LIST ETI 482A

Resistors all ½ W 5%

R1,2	1 k
R3,4	56 k
R5-R8	1 k
R9-R14	33 k
R15,16	1 k
R17,18	56 k
R19,20	560 k
R21,22	47 k
R23-R26	1 M
R27,28	47 k
R29-R34	100 k
R35,36	1 M
R37-R40	100 k
R41,42	220 k
R43,44	1 k
R45	15 k
R46,47	10 k
R48	15 k

Semiconductors

Q1- Q4	Transistor BC549
IC1, 2	Integrated Circuit 741
*IC3,5,6	Integrated Circuit 4016
IC7-IC10	Intergrated Circuit 741

*The number IC4 is not used

PC Board	ETI 482A

Potentiometer

RV1	1 Meg Dual lin rotary

Capacitors

C1,2	1 μ 35 V Tantalum
C3,4	47 p ceramic
C5,6	1n0 polyester
C7,8	10 μ 16 V electro
C9,10	5n6 polyester
C11-C14	1 μ 35 V electro
C15,16	3n3 polyester
C17,18	1 μ 35 V electro
C19-C22	10 μ 16 V electro
C23	47 n polyester

PARTS LIST ETI 482B

Resistors all ½ W 5%

R49,50	1 M
R51,52	100 k
R53,54	27 k
R55,56	5k6
R57,58	1 M
R59,60	5k6
R61,62	1 M
R63,64	27 k
R65,66	5k6
R67,68	47 k
R69,70	27 k
R71,72	5k6
R73,74	1 k
R75	15 k
R76,77	10 k
R78	15 k
PC board	ETI 482 B

Potentiometers

RV2	10 k log dual rotary
RV3	100 k lin dual rotary
RV4	25 k lin dual rotary

Capacitors

C25,26	10 μ 16 V electro
C27-C30	68 n polyester
C31,32	8n2 polyester
C33,34	2n7 polyester
C35-C38	10 μ 16 V electro
C39,40	22 n polyester
C41,42	560 p ceramic
C43,44	10 μ 16 V electro

Integrated Circuits

IC11,12	4016 or 4066
IC13-IC16	741

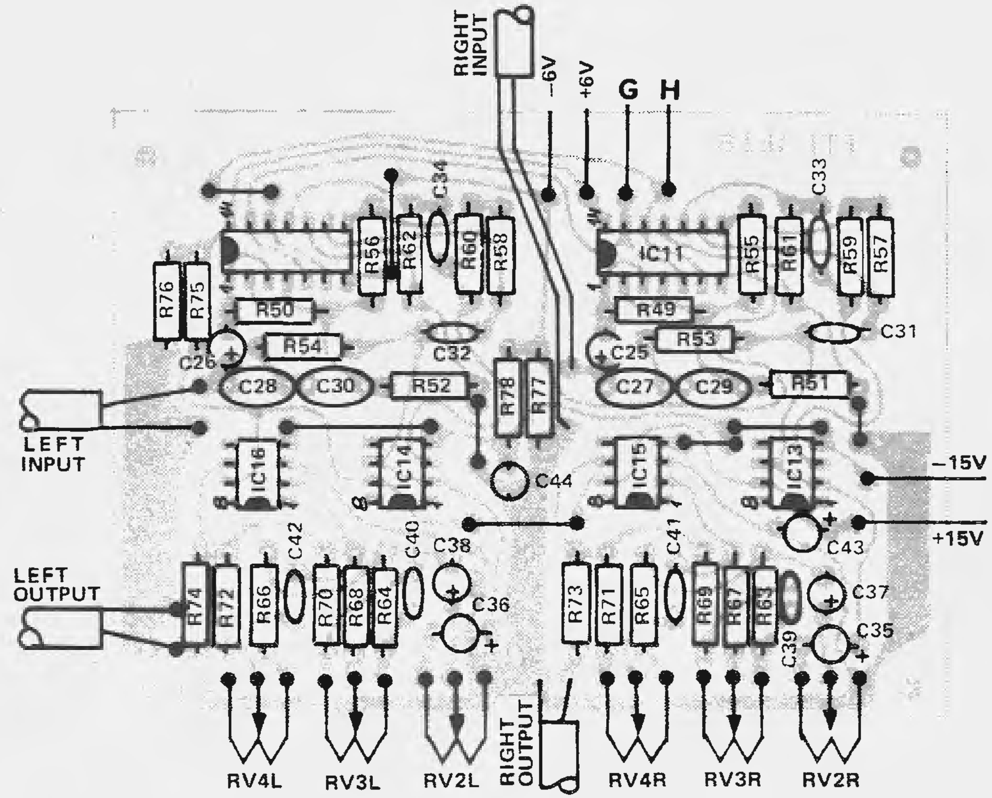
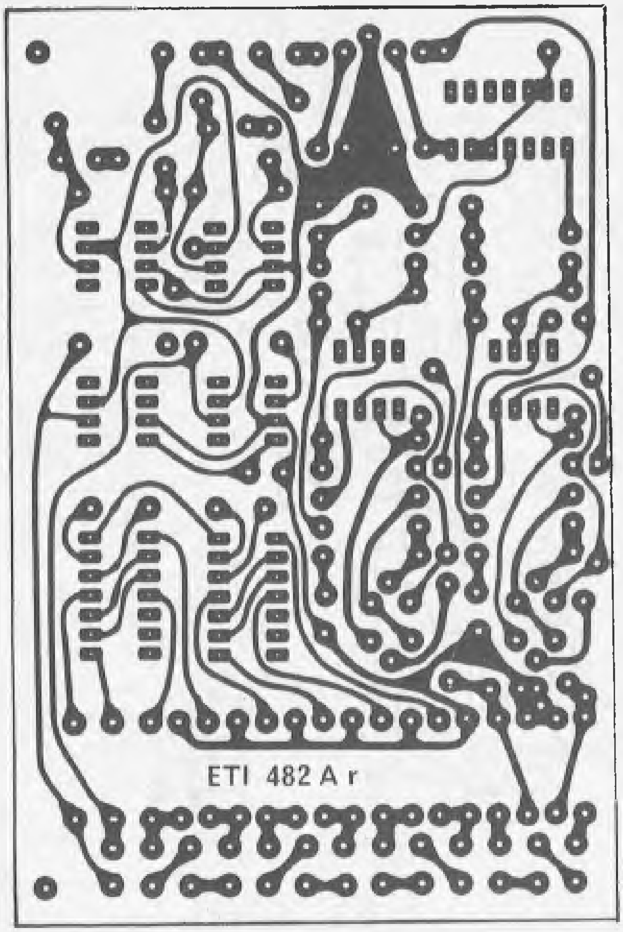
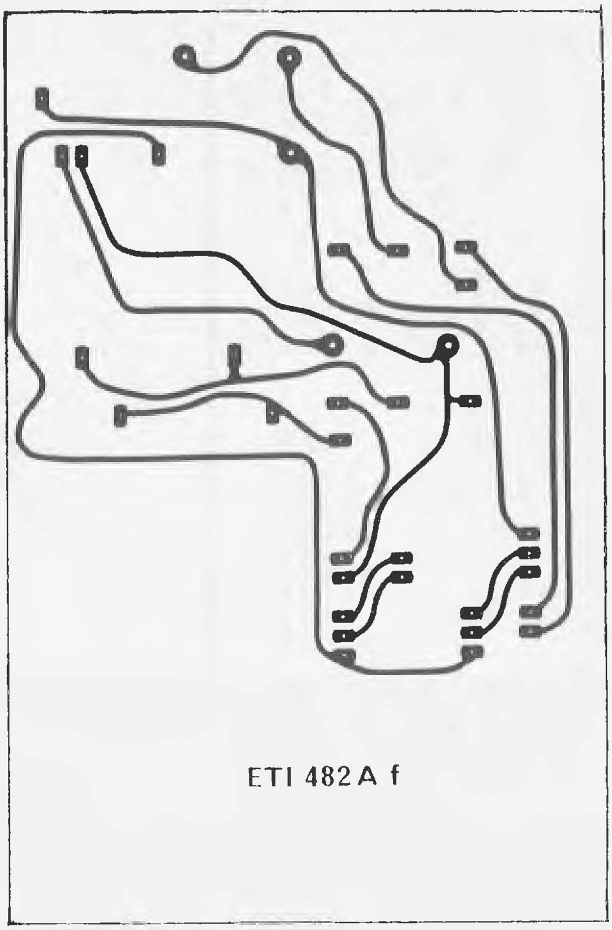
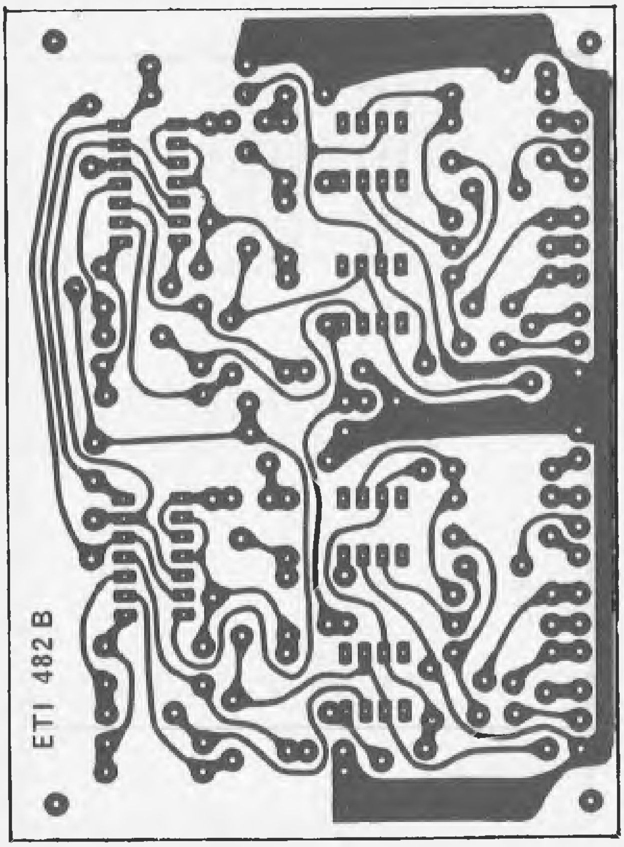


Fig 5. Component overlay of the filter and tone control board.

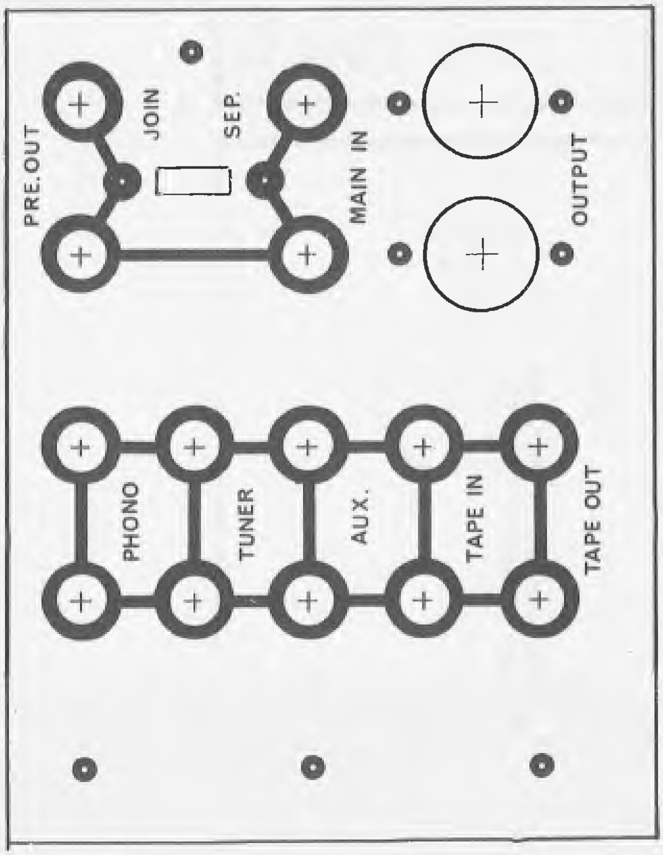




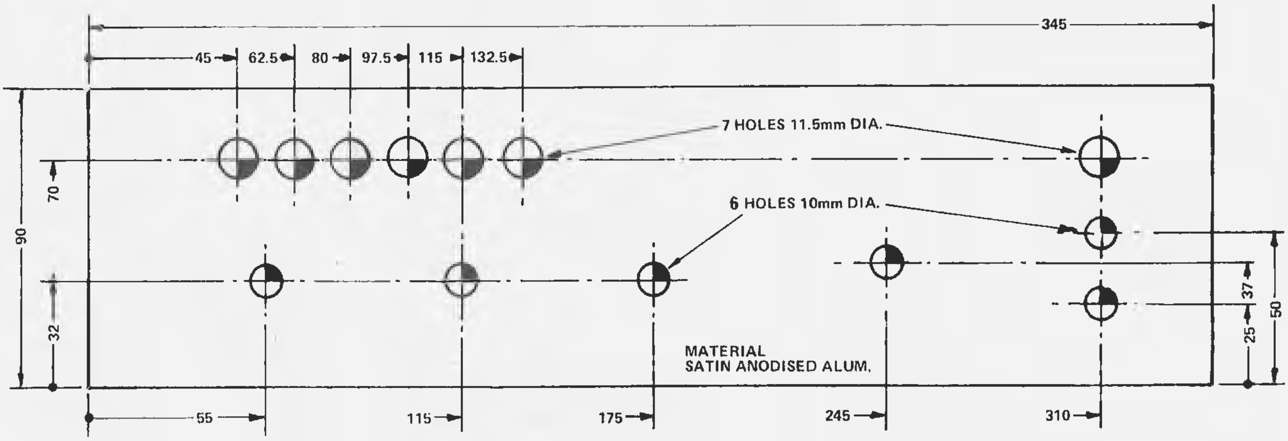
Printed circuit layout(both sides) of the preamp board. Full size 120 x 80 mm.



Printed circuit layout of the tone control board.Full size 110 x 80 mm.



Details of the rear panel. Material 1.6mm fibreglass 1oz cu board.



Details of the front panel.

An internal view of the amplifier. Note that the preamp board is pivoted out and not in its final position which is parallel with the rear of the unit.

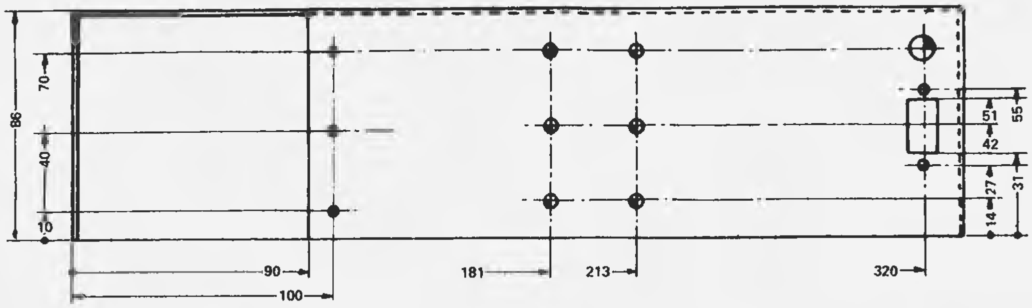
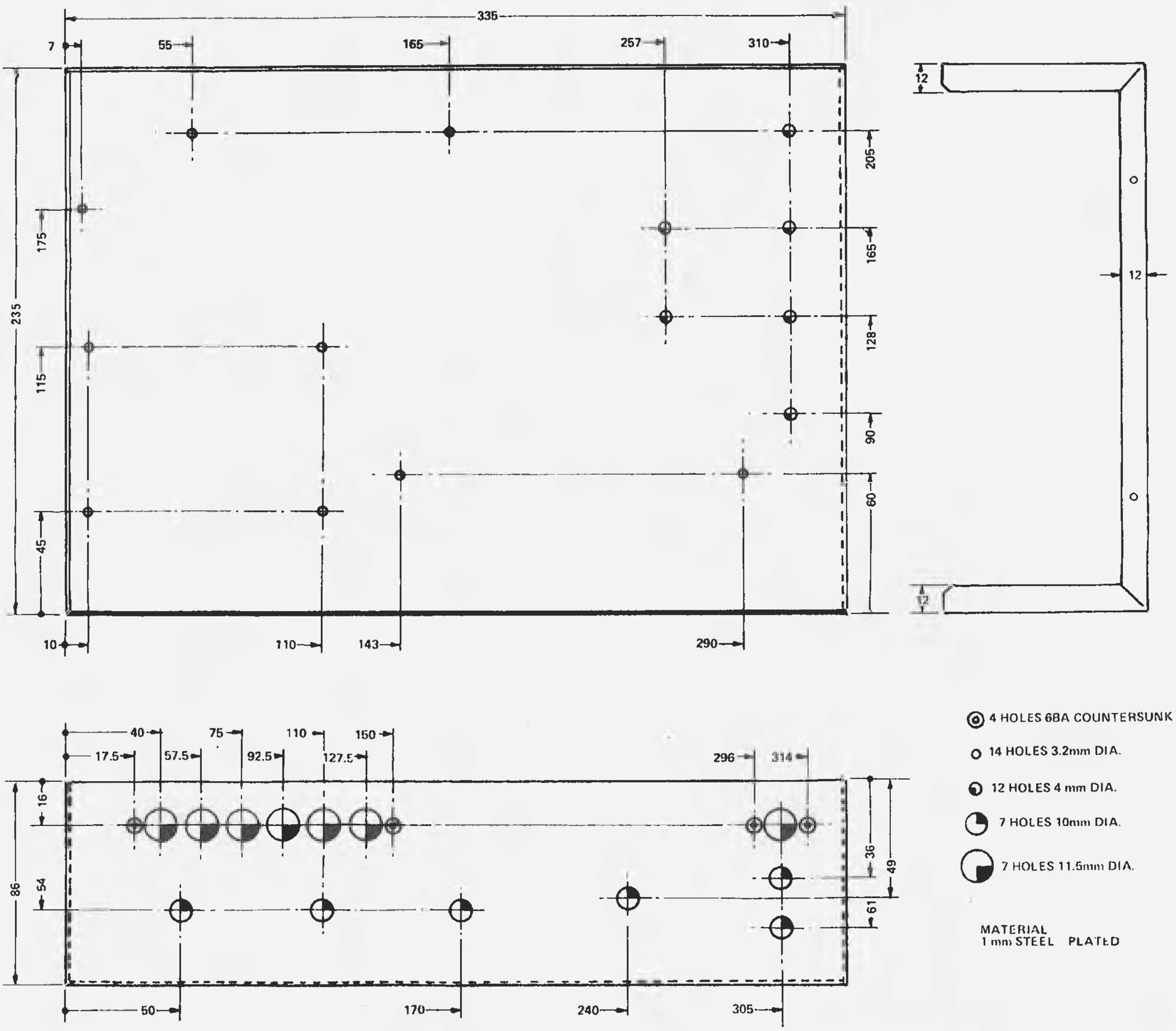


Fig 2. Details of the chassis.



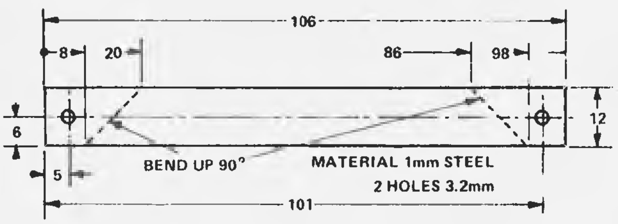


Fig 3. The bracket used to support the rear panel.

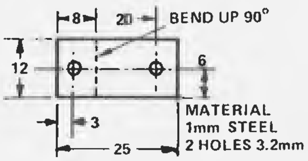
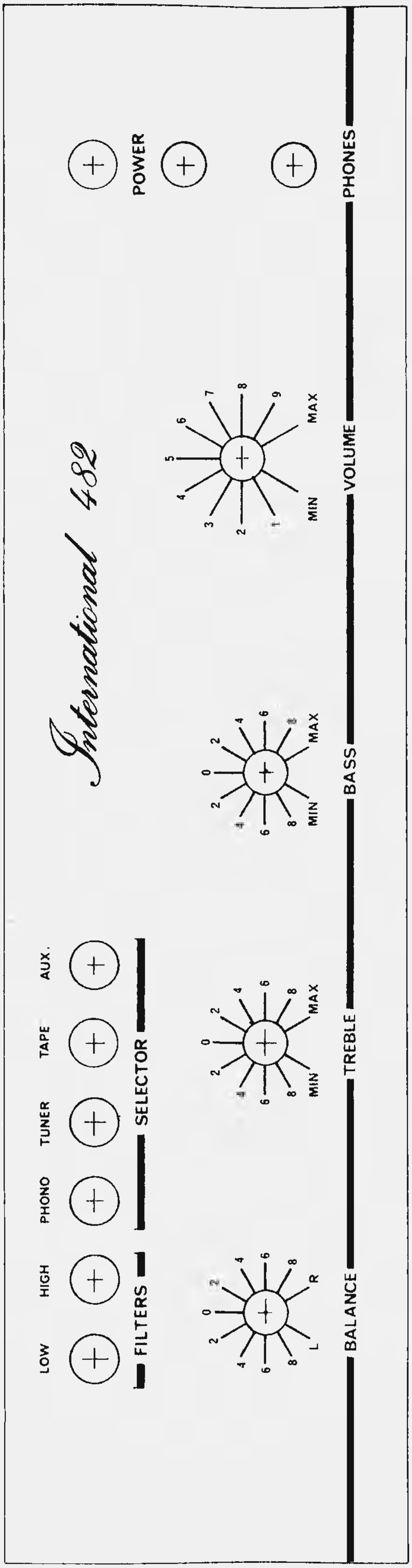


Fig 4. The brackets used to support the preamp and power supply boards. 4 required.



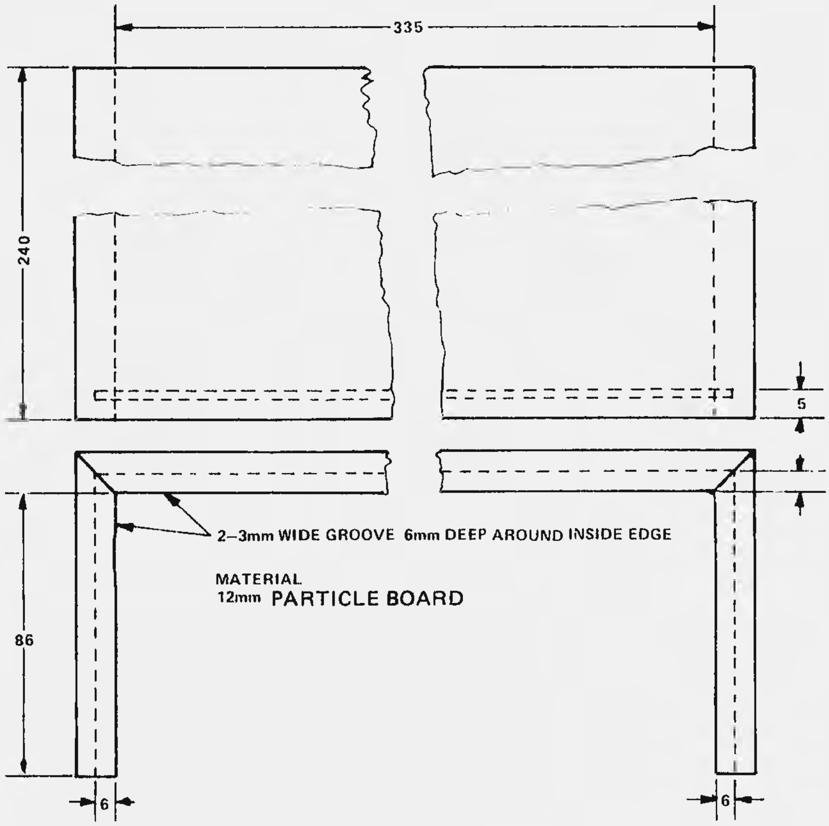
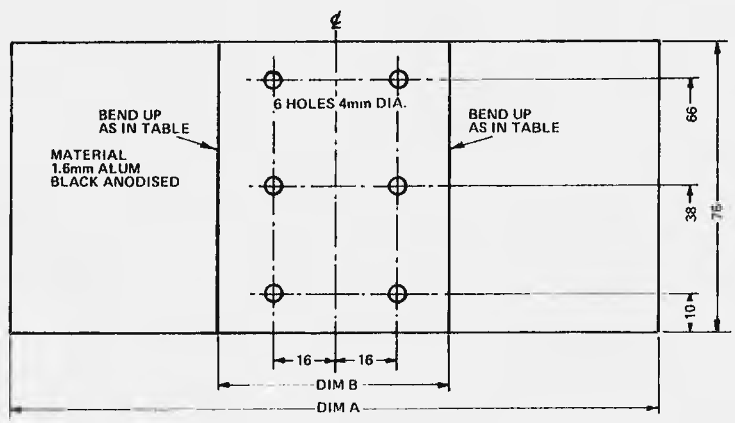


Fig 5. The wooden cover.



	DIM A	DIM. B	ANGLE
ITEM 1	110	40	75°
ITEM 2	130	50	60°
ITEM 3	170	60	45°
ITEM 4	230	70	30°

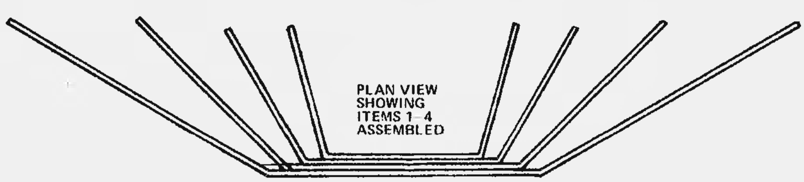
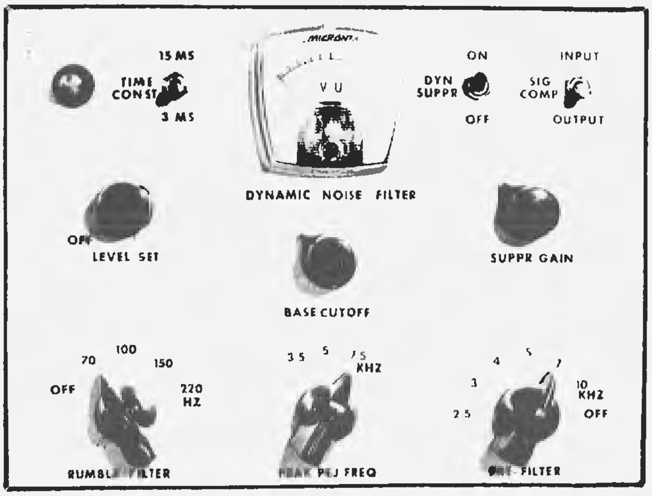


Fig 6. Details of the heatsink used.



DYNAMIC NOISE FILTER

by M.G. Strange

Flexible low-cost noise filter virtually eliminates record surface noise.

DESPITE denials from many record manufacturers, many present day recordings have excessively loud surface noise — and this cannot be reduced using conventional tone controls without also losing a substantial amount of the programme content.

Serious collectors of older recordings have an even more serious problem. Most of these records are quite noisy — even by today's standards. For example, 78 rpm commercial discs, even though in mint condition, will have a typical signal-to-noise ratio of only 30 to 35 dB due to the abrasive nature of the record material.

Many collectors dub their best records onto tape. This way they may be played as often as desired — and conveniently shared with other collectors — while the often irreplaceable originals are safely preserved. Also, the sound can often be improved considerably during the copying process through equalization and filtering.

This article describes a flexible, low-cost noise filter designed for taping records with a maximum "fidelity-to-noise" ratio. It can be duplicated by the serious electronics hobbyist for about $80, or slightly less if certain features or ranges won't be needed. Although not recommended as a beginner's project, the experimenter with some circuit experience should have no difficulty. Minimum equipment requirements are an oscilloscope, sine wave generator, and multimeter.

The heart of this circuit is a dynamic noise suppressor with frequency characteristics and convenience features which are optimized for its intended use. The concept of dynamic noise suppression has existed for many years. Workable circuits were designed by H.H. Scott in 1946, and their performance was improved by Scott and others in 1947 and 1948. Then with the advent of the vinyl microgroove record and the rapidly increasing use of tape, both of which offered a considerable noise improvement over the 78 rpm system, the dynamic noise suppressor was almost forgotten. Recently, R. Burwen has revived this principle and applied it primarily to tape playback. Taking full advantage of modern integrated circuits, Burwen has designed highly sophisticated and flexible systems with impressive specifications. These, however, are too expensive for many hobbyists and do not have frequency characteristics optimized specifically for old, intrinsically band-limited material.

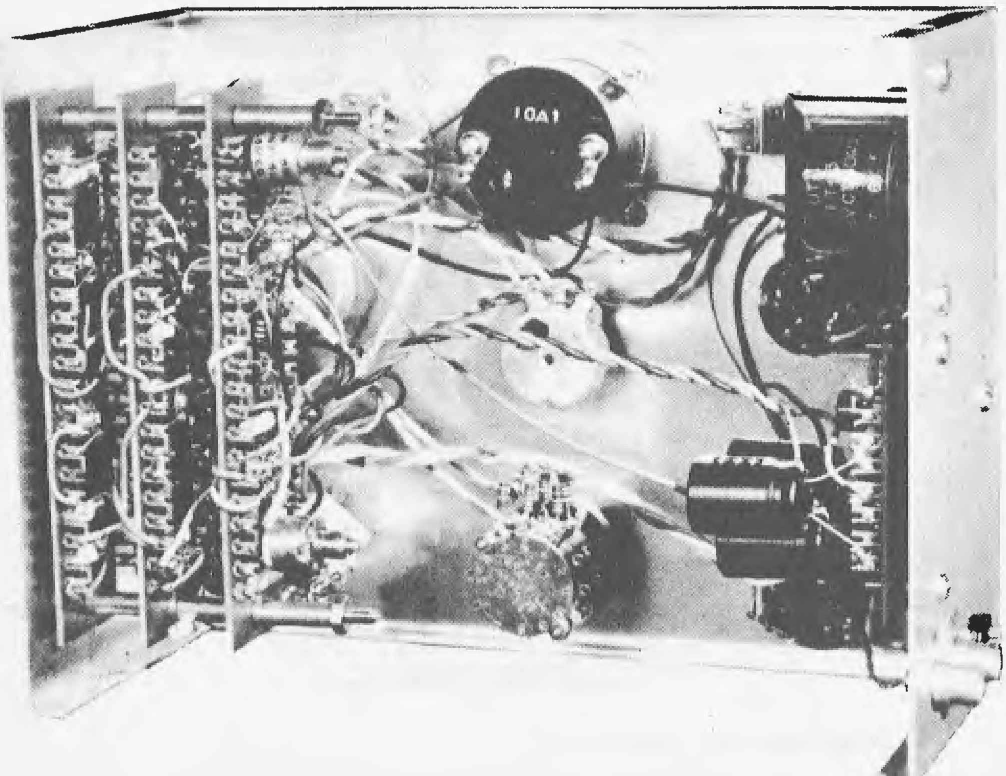


Fig. 1. Interior of prototype unit.

THEORY

Dynamic noise suppression is simple in concept. Record surface noise varies in spectral content, but the higher frequencies (above 1 or 2 kHz) predominate. Low-pass filtering is commonly used to limit noise. But unless used sparingly, this type of filtering band-limits the programme material, making it sound muffled and lifeless. The dynamic filter, however, provides a method by which a signal can be effectively extracted from the noise (at least subjectively) *when signal and noise occupy overlapping frequency ranges.*

Operation of the dynamic noise suppressor depends upon a characteristic of the human auditory apparatus. If two signals occupying well-separated frequency ranges are present simultaneously, they are clearly perceived as individual entities. (This effect is often used to advantage in public address systems for noisy environments. If considerable high-frequency boost is used, voice announcements will seem to cut through ambient noise of predominately lower frequency without having to be excessively loud.) This is the case, at least for a large portion of the time, for a typical recorded signal with attendant surface noise; hence, the annoyance of the noise. However, if two simultaneous signals occupy substantially the *same* frequency ranges, the ear will tend to hear only the louder signal and ignore the weaker one. A level difference of only a few dB is sufficient for one signal to effectively override, or mask, the other. Operation of the dynamic noise suppressor depends upon this masking effect.

The dynamic filter has a fairly steep low-pass characteristic which, in the absence of signal, starts cutting off at about 1 kHz. This very effectively rejects the noise spectrum. When a signal having high-frequency components at sufficient amplitude comes along, the filter is made to "open up"; that is, its cutoff frequency is quickly raised. As the high-frequency programme content drops in frequency and/or amplitude, bandwidth contracts. The idea is that when high-frequency signal components are present, they will tend to mask the accompanying noise. When highs are not present, the wide bandwidth is not needed. Admittedly, the recovered signal is not as faithful as a noise-free original would be. For example, high-frequency content in low-level passages may be lost. Of some help here is the fact that many musical instruments tend to have less harmonic content at low acoustic levels. In spite of this compromise, the processed signal is usually far more pleasing to the ear than the noisy input signal.

The bandwidth control signal is derived by separating the high-frequency programme components from the signal-plus-noise. Unless the signal level is consistently higher than the noise to begin with, this becomes impossible. Thus, there is a minimum signal-to-noise requirement below which no improvement is possible. As the original S/N improves, the dynamic suppressor's performance improves also.

Ideally, the signal frequency range to which bandwidth is most sensitive should correspond to the frequency range of maximum noise. The optimum filter characteristic for separating the bandwidth-control signal from the noisy input thus varies widely with the characteristics of the noise with which we are dealing. Bandwidth control sensitivity (or gain) must be set properly for the incoming signal level and noise properties. Bandwidth should respond rapidly to signal changes to avoid loss of transients and to prevent audible "swishing" sounds which can be produced by delayed bandwidth contraction.

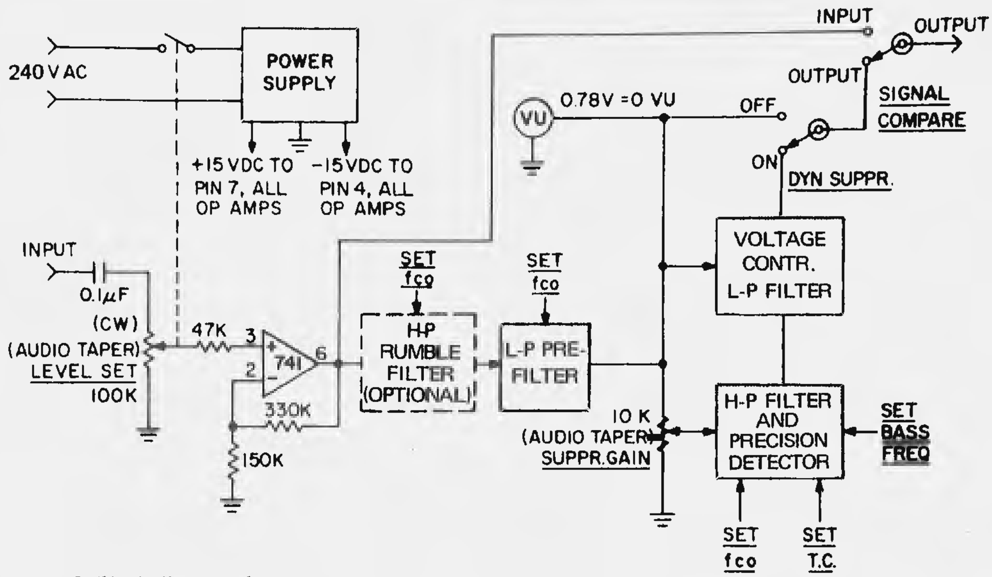


Fig.2. Block diagram of system.

DESIGN APPROACH

I have tried to implement the basic requirements outlined above as completely as possible in an easy-to-use, low-cost unit. A dynamic high-pass filter stage was considered but later dropped, as high-frequency noise predominates on most older records. Low-frequency noise can usually be handled adequately with a simple manually-set rumble filter.

Figure 2 shows an overall block diagram of the noise filter. Operational amplifier A1 is connected as a non-inverting amplifier with a voltage gain of 3.2 (10 dB), enabling the system to be driven to 0 VU with an input level of 0.25 volt. This amplifier also serves as a buffer, providing an input impedance of 100 kilohms for compatibility with virtually any signal source.

Amplifier A1 drives the *rumble filter,* which could be omitted if one is available in the associated external equipment. Following this is the *pre-filter*, which is simply a low-pass filter with a manually set cutoff. This filter is important for several reasons. First, it removes noise which is above the frequency range of the recorded signal. Many recordings have no signal content above 4 or 5 kHz (even lower for acoustic records), and no programme content is lost by cutting off the upper range. Thus, the total noise voltage is lowered, often appreciably, permitting the use of higher suppression gain settings as will be seen later. Another reason for this filter is that the dynamic filter can do nothing to reduce the annoyance of high-frequency distortion. Furthermore, since a limited-bandwidth signal cannot effectively mask higher-frequency noise, removal of the latter helps to eliminate audible evidence of the continually changing bandwidth.

From the pre-filter output the signal passes to the *voltage-controlled low-pass filter* and, via the *suppression gain* control, to the *high-pass filter/precision detector* whose function is to derive the bandwidth control signal. This point additionally goes to a switch which permits the dynamic filter to be by-passed at will so that its effect with various control settings may be easily judged. Another switch permits the output to be compared with the "raw" input signal.

All of the filters used in this system, including the voltage-controlled filter, are of the 2-pole active type, giving a 12 dB/octave rolloff slope. The damping factor is chosen (with one exception) for a Butterworth response, which produces the steepest possible slope beyond cutoff with no peaking in the passband. (High-pass filters with 3 dB peaking were tried, but these produced a slightly rough, "grainy" sound compared to the flat-passband version.) The design approaches are widely published and need no further discussion here. The rumble filter

DYNAMIC NOISE FILTER

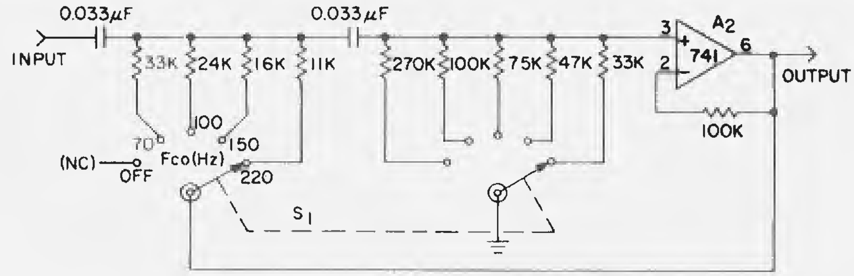


Fig.3. Optional high-pass rumble filter schematic.

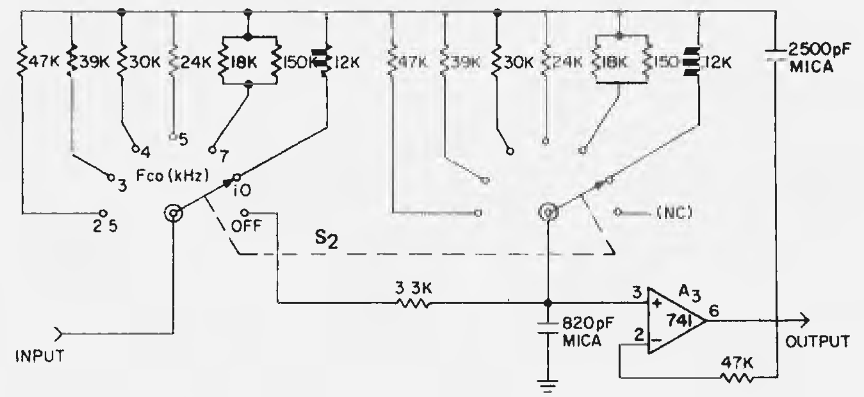


Fig.4. Schematic of the low-pass pre-filter.

(Fig. 3) and the pre-filter (Fig.4) are of this type; their response curves are shown in Fig.5. The rumble filter is not essential to proper suppressor operation, but is convenient in case an effective low-cut filter is not included with the associated preamplifier in the copying setup. The design shown here has rather high settings intended primarily for acoustic records.

The bandwidth control signal is derived with the circuit of Fig. 6, which consists of a high-pass filter followed by a precision detector. The filter damping factor is made low in order to produce a pronounced peak and more rapid low-frequency rolloff (Fig. 7). Three selectable cutoffs produce peaks at 3.5, 5, and 7.5 kHz; these were empirically determined to best accommodate a wide range of noise characteristics and recorded bandwidths.

The knowledgeable enthusiast could readily modify the cut-off points to suit his own particular application.

The filter output is coupled to the detector via a small capacitor to make the low-frequency rolloff even steeper below 1.6 kHz. The precision full-wave detector uses diodes in the feedback circuit of an op-amp to effectively produce ideal rectification characteristics down to the millivolt region. The output amplifier doubles as a post-detection filter. Resistor R determines the gain, and capacitor C makes this stage behave as an operational integrator with time constant RC. A switch is provided for increasing the time constant by paralleling capacitor C1; this is helpful with sources having sharp impulse noise. The output of the detector/filter circuit controls the bandwidth of the dynamic suppression filter according to the curve of Fig. 9.

Early experiments showed that it is undesirable to make the no-signal cutoff lower than absolutely necessary to substantially reduce noise with a particular signal source. When the cutoff is made lower than actually needed, weak signals are unnecessarily band-limited and the dynamic filter produces such a level-dependent bandwidth contrast that its action is much more likely to be audible. Hence a BASE CUTOFF (not "BASS CUTOFF") control was found to be desirable. This control is simply a pot which offsets the detector output at zero signal level by applying a variable reference voltage to the op amp non-inverting inputs. This voltage, variable from about −1 volt to −6 volts, establishes a "starting point" or base cutoff frequency which can be set just low enough to virtually eliminate no-signal noise.

The variable-cutoff filter, Fig. 8, is the very heart of the system. Since there is some part selection and adjustment necessary, it must be checked out separately. The basic configuration is similar to that of the pre-filter, except the latter's switch-selected resistors have been replaced by field-effect transistors (FETs). FET channel resistance R_{DS} changes as a function of gate voltage V_{GS} as shown in Fig. 11, thus varying cutoff frequency. A resistor across each FET establishes a solid lower cutoff limit and smooths the control characteristic as the FETs approach their "off" state. The gate circuit network, consisting of diode D1 and resistors R1 through R5, is used to empirically shape the control curve (Fig. 9) for best audible results. Diode D1 prevents excessive positive gate drive, maintaining isolation between the gate and signal circuits.

An input attenuator (R10 and R11) limits the signal amplitude presented to the FETs to about 0.1 volt p-p at 0 VU to ensure low distortion. Output amplifier A7 makes up exactly for this loss. An op amp having external frequency compensation was used here so that this relatively high-gain stage could be tailored for flat response to 15 kHz (a µa741 could be used, but would roll off slightly above 10 kHz). Resistors R16 and R17 attenuate the output signal by an amount equal to the gain, so that this amplifier doubles as the unity-gain buffer required for filter operation. The highest cutoff frequency is dictated by minimum FET resistance and capacitors C1 and C2. The latter should have values in a ratio of about 3:1 to produce the

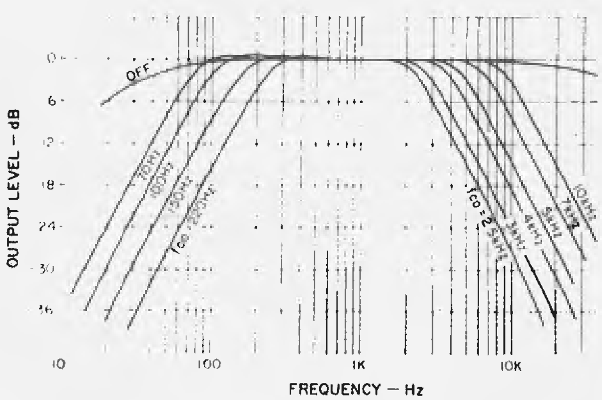


Fig.5. Frequency characteristics of the manually-set rumble filter and pre-filter.

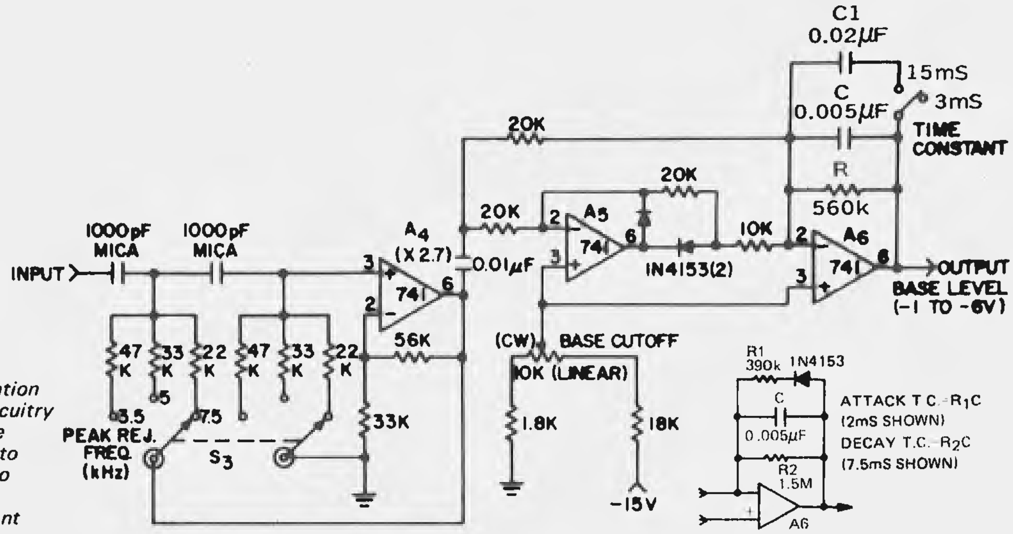


Fig.6. Bandwidth control signal separation filter and precision rectifier. IC A6 circuitry may be modified, as shown in separate detail, for shorter attack with respect to decay time — note that R1 and R2 also affect rectifier gain so time constant changes are not completely independant of 'suppression' gain.

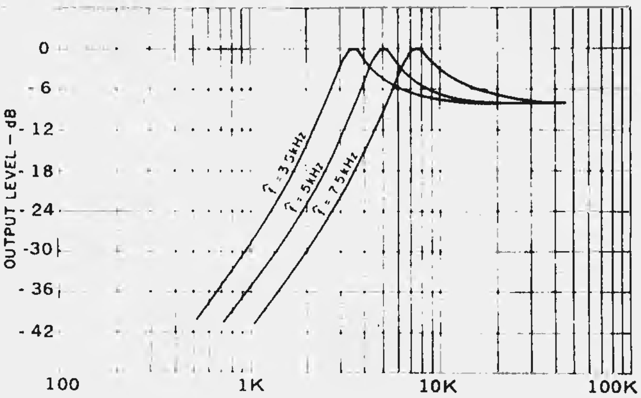


Fig.7. Frequency characteristics of the filter used to derive the bandwidth control signal.

desired Butterworth response. Figure 10 shows the measured response of the complete filter for four values of control voltage.

Unfortunately, FETs vary widely in characteristics, even between units of the same type, so these devices must be selected. The two FETS must be reasonably well matched over at 15:1 R_{DS} range for a 15:1 range in cutoff frequency (15 kHz to 1 kHz). (Dual matched FETs are available, but are more expensive and not necessarily matched for the parameter of interest here.) A transistor curve tracer is most convenient for this purpose and permits selection for best linearity as well as matching. I used N-channel 2N4220s on hand ($1.50 each) and selected the best matched pair out of a group of six units. Figure 11 shows the VI characteristics of one of these. There are many other inexpensive FETs which should work as well, such as the 2N5484, 2N5716, and 2N5717. In fact, any general-purpose, depletion-type FET with fairly low zero-bias current (I_{DSS}) and pinch-off voltage (Vp) should be usable. P-channel units would require reversing diodes D1 and D2 and the polarity of the control voltage.

If a curve tracer is not available, the setup of Fig. 12 can be used. A transistor socket will facilitate changing FETs. A good procedure is to first measure R_{DS} at $V_{GS} = 0$. Then increase V_{GS} (negatively for N-channel FETs) until R_{DS} is about three times the zero-bias value; this corresponds to a mid-range cutoff frequency where matching is the most critical. With this V_{GS} setting try different FETs until a 10 percent or better match is found. If R_{DS} values seem to cluster higher or lower, try another unit as a reference and try matching to it. When matched units are found, check the match at minimum R_{DS} ($V_{GS} = +0.5V$) and at 10 times this value of R_{DS}. A 20 percent mismatch can be tolerated at

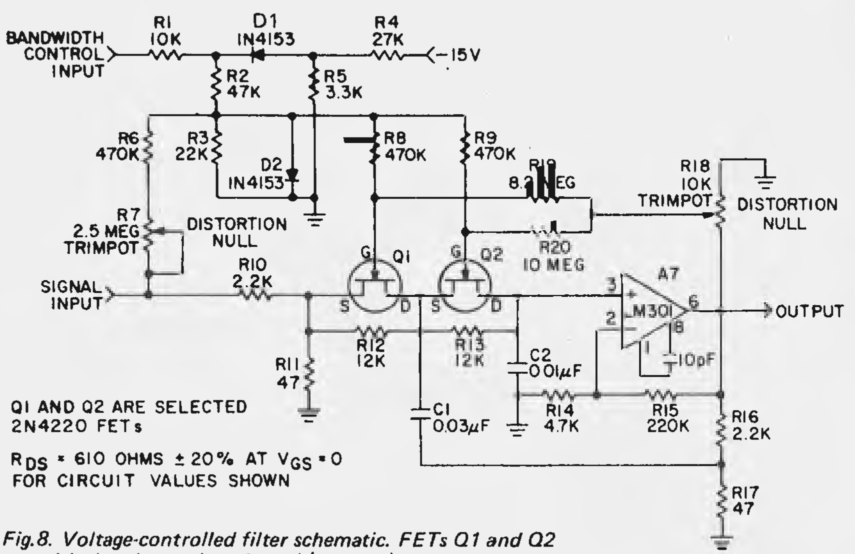


Fig.8. Voltage-controlled filter schematic. FETs Q1 and Q2 are critical and must be selected (see text).

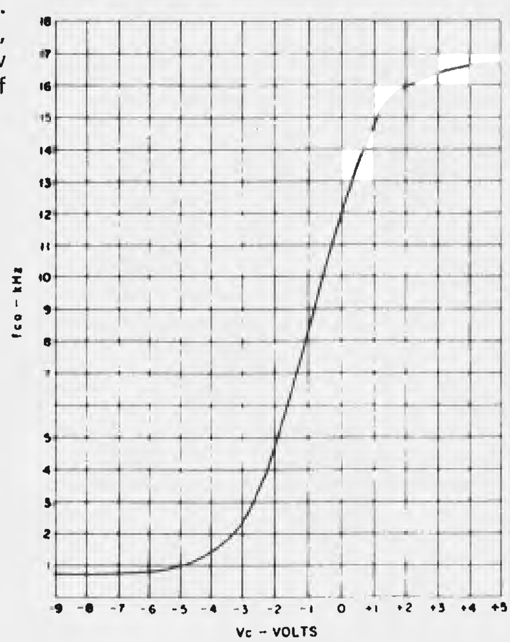


Fig.9. Variable-bandwidth filter cutoff frequency vs. control voltage.

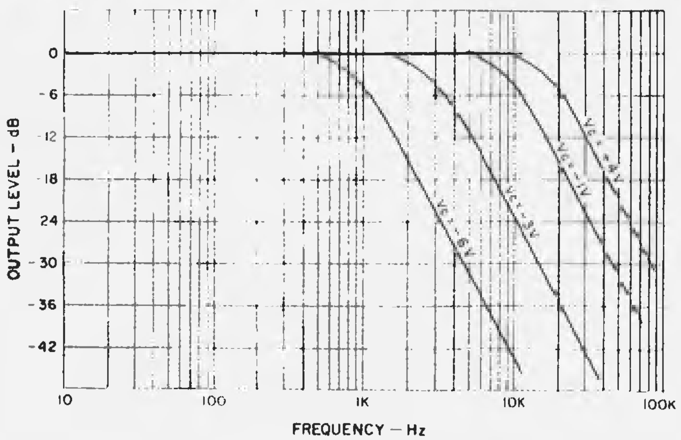


Fig. 10. Variable-bandwidth filter characteristics for several control voltage values.

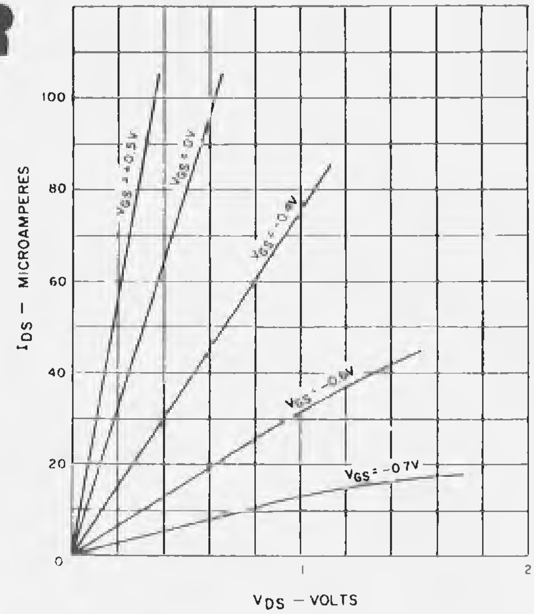


Fig. 11. Variable-resistance characteristics of a junction field-effect transistor with low values of drain-to-source voltrage.

these extremes. My 2N4220s measure 610 ohms at zero bias, 360 ohms at V_{GS} = + 0.5V., and about 8 kilohms at V_{GS} = –0.7 V. R11 and R12 are chosen for a cutoff of between 800 Hz and 1 kHz with the control voltage at its maximum negative value of about –6 volts. Circuit cutoff at zero FET bias should be roughly 12 kHz (see Fig. 9). A slight forward bias, limited to about +0.5 volt at the FET gates by diode D2, then boosts the cutoff to at least 15 kHz with maximum positive output from the precision detector.

Resistors R6, R7, R18, R19, and R20 reduce harmonic distortion significantly. R6 and R7 feed some signal to the FET gate circuit so that signal voltage does not appear between source and gate, which would make R_{DS} vary slightly with instantaneous low-frequency signal amplitude and polarity. R18, R19, and R20 feed back some output signal to the gates to further reduce distortion (this is a cancellation effect, not true negative feedback).

Distortion settings are best made in the vicinity of cutoff, where FET linearity is the most critical. Connect a variable-voltage d.c. source (the slider of a 5 k pot temporarily connected between – 15 V and ground will suffice) to the bandwidth control input and set it for a cutoff frequency of 2 kHz. Then, with a 2 kHz sinusoidal input at about 0 VU (2.2 V p-p), set trimpots R7 and R18 for lowest harmonic distortion at the output. It should be possible to sharply null the total harmonic content, which consists primarily of the 2nd and 3rd harmonics, to at least 60 dB below 0 VU. Then vary the cutoff frequency and make sure distortion is low for all settings. Of course, the filter itself will reduce harmonic distortion appreciably at its lower cutoff values. Lacking a distortion meter or wave analyzer, these adjustments can be made quite well by driving the input at 7 volts p-p (10 dB above 0 VU) to accentuate the distortion and setting very carefully for a symmetrical output waveform as monitored by a 'scope. Fixed resistors, determined by two decade boxes (the settings interact somewhat), could replace the pots. These adjustments, once made, are permanent unless the FETs are changed.

Figure 13 shows the distortion of the complete noise filter measured at two fixed values of bandwidth control voltage. At normal levels, distortion is so low that it is largely a measurement of the harmonic distortion of the test oscillator. The large margin above 0 VU passes the highest programme peaks ever likely to be encountered without clipping.

The simple power supply of Fig. 14 easily supplies the power requirement of ± 15 volts at about 10 mA.

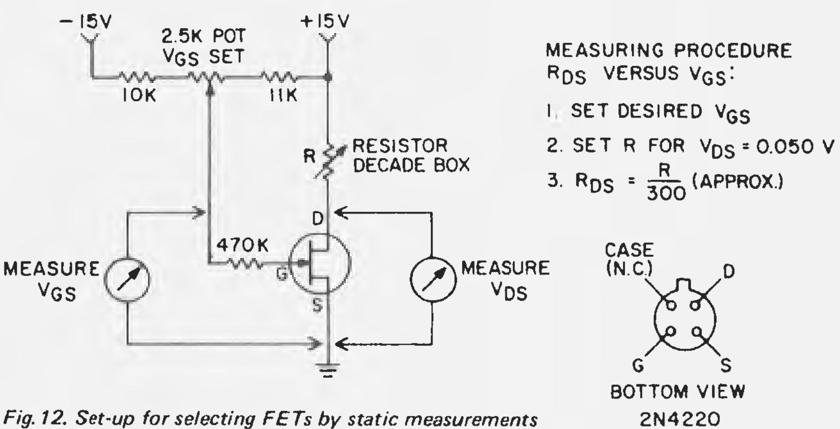


Fig. 12. Set-up for selecting FETs by static measurements (see text). Small 15 V batteries or the power supply of Fig. 13 may be used.

CONSTRUCTION

The entire filter can be duplicated for about \$80 with new parts. Very few components are critical and substitutes can be used in most cases. Quarter-watt, 5 percent composition resistors are suitable. Layout is not critical, since signal levels are high and impedances are relatively low. I strongly recommend that each of the functional blocks of Fig.2 be built and checked for reasonable conformance with the curves before integration into the system. This makes troubleshooting for errors and occasional bad components much easier, practically ensuring success. My unit (Fig. 1 and lead photo) is a "breadboard in a box." The circuit is still undergoing occasional changes, even though it is a third-generation model. Parts are mounted on terminal boards which were on hand. A neater approach would be to use the

commercially-available matrix-board with snap-in terminals.

OPERATION

After checking the wiring, apply power to the unit and check for proper power supply voltages. Positive and negative supplies should both be between 14 and 16 volts with respect to ground. Much lower values would indicate a short circuit or bad op amp. Current drain should be on the order of 10 mA.

The noise filter can be conveniently connected to your audio system by means of the *Tape In* and *Tape Out* jacks included on most preamplifiers. An advantage to this connection is that the processed signal passes through the pre-amp tone controls, which can be set for the most pleasing final balance. For taping, the recorder input is paralleled with the output which drives the power amplifier.

For intial set-up experience, a record having a good frequency range and moderate, steady surface hiss is desirable. (A slightly noisy FM station can also be used, but results will not be quite as good because of the latter's flatter noise spectrum.) Initial control settings should be:

Pre-Filter: Off
Rumble Filter: Off
Time Const.: Off
Peak Rej. Freq.: 5 kHz
Base Cutoff: CCW
Suppr. Gain: CCW
Dyn. Suppr.: Off
Sig. Compare: Input

The signal should now pass through the unit unaffected, except the *Level Set* control will vary the gain from zero to 3.2 (10 dB). Set the level for 0 VU on signal peaks as you would set a recording level. Whenever the source is changed, the signal level should be reset as necessary.

Now switch the *Sig. Compare* switch to "output". The signal is now passing through the rumble filter (if used) and pre-filter, but bypassing to dynamic filter. Lowering the *Pre-Filter* cutoff setting should progressively cut off the highs. At the lower settings, which are primarily for acoustic records, the signal will sound severely band-limited. The best setting is the lowest cutoff which does not significantly affect the recorded bandwidth. I have found that with vocal music, the unfiltered sibilant sounds provide a means of judging bandwidth. If sibilants are quite strong and natural, a 7 kHz or higher cutoff is indicated. If they are weak or have a slight "whistling" sound, the upper limit is about 5 kHz. If sibilants are lacking, a 4 kHz or lower setting is best. Of course, the presence of high-frequency distortion may dictate a compromise setting a notch or two lower than indicated above. The filtered and unfiltered sounds may be compared at any time by means of the *Sig. Compare* switch.

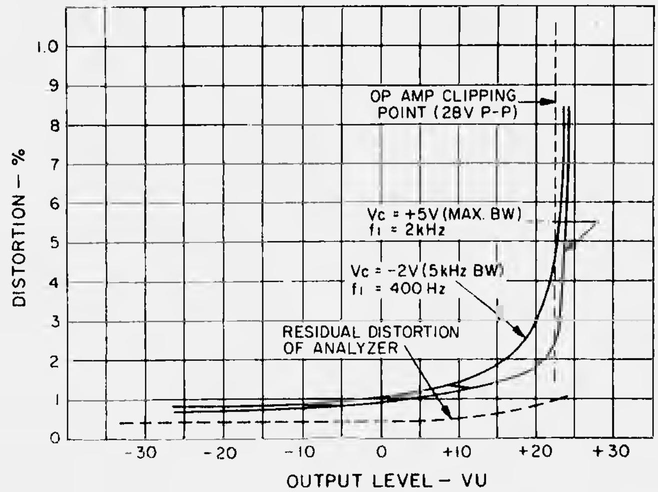


Fig. 13. Overall harmonic distortion of the noise filter for two constant values of bandwidth-control voltage.

The optional rumble filter is used for the occasional records which have warpage or bumps or low-frequency noise in the recording. For *acoustic* records it can be routinely left at 150 Hz, as nothing is recorded below about 200 Hz.

Next flip the *Dyn Suppr* switch to "on", putting the dynamic suppressor in the circuit. The sound should become very dull and lifeless, as the high-frequency cutoff is now 1 kHz or less. Increase the *Base Cutoff* setting until record noise just begins to be audible. The signal will probably still be quite lacking in high-frequency content (if it is not, only the pre-filter may be needed for this particular source). Now turn up the *Suppr Gain* slowly. This should "magically" restore the highs without increasing the noise level. The highest possible setting which does not noticeably increase the noise is normally best.

At this point it is edifying to monitor the bandwidth control input signal to the variable-bandwidth filter with a d.c.-coupled oscilloscope. The instantaneous voltage here is a measure of high-frequency programme amplitude and dynamic filter bandwidth (see Fig. 9). It should follow transients rapidly and may reach saturation (about + 14 volts) on musical passages having high harmonic content and on strong voice sibilants.

The *Peak Rej. Freq.* switch selects the frequency of peak rejection by choosing the appropriate filter curve (Fig. 7) for separating the bandwidth-control voltage from the input signal. The *5 kHz* position is used for most electrical 78 rpm records. For acoustic records or very noisy electrical 78s where the pre-filter is set for 4 kHz or less, the *3.5 kHz* position gives better results. Here the *Time Const.* switch can be set for *15 mS.* The longer time constant also helps to attenuate sharp clicks and pops occuring in quiet passages, as it prevents the bandwidth from increasing rapidly enough to follow their steep wavefronts. The *7.5 kHz* position is used for wideband recordings and tape.

With a little practice, you will be able to set the controls quickly for optimum performance. It is often best to set the *Base Cutoff* for a significant improvement, rather than to try to eliminate the noise completely. This will minimize low-level band limiting, and the suppressor will be less likely to betray its presence with obvious bandwidth changes.

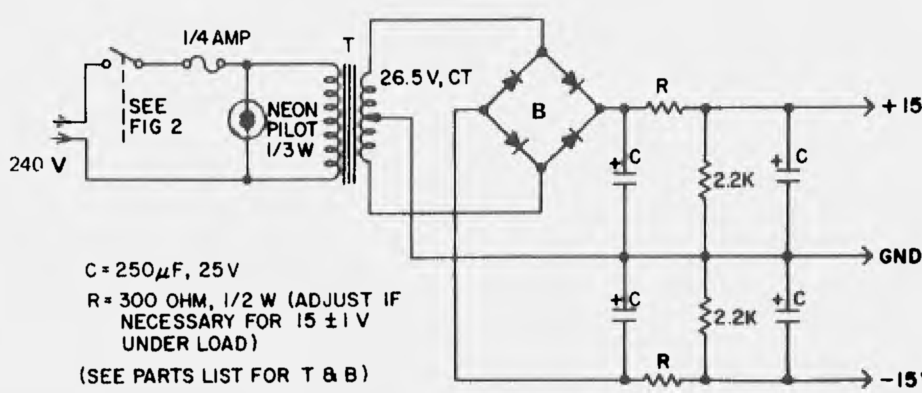


Fig. 14. Power supply. A two-channel suppressor may easily be powered by reducing R slight.y

DYNAMIC NOISE FILTER

PERFORMANCE

Figures 5 and 10 indicate the bandwidth ranges available. The pre-filter and dynamic filter (slope is 24 dB/octave above both cutoffs) can together provide well over 60 dB of noise attenuation at 10 kHz and over 40 dB at 5 kHz. The overall improvement in signal-to-noise ratio is strongly determined by the character and spectrum of the noise, which varies greatly with records. With the steady hiss typical of new electrical recordings on shellac, an average improvement of 8 dB (unweighted) is realized from the dynamic filter alone. Including the effects of the rumble filter and pre-filter on band-limited material, S/N improvement can be more than 12 dB. The apparent improvement is even greater, since the ear heavily weights the higher frequencies where record noise is concentrated.

The effect of the noise filter is surprisingly great on records which were originally thought to be quiet without filtering. It is a little weird at first to hear a familiar old record with realistic strings and brass and clear voice sibilants, but with the background suddenly rendered deadly quiet. I have spent many hours listening to the records and tapes in my collection and enjoying them anew.

The noise filter works very well on tape noise, providing at least 8 dB total S/N improvement. A stereo version built for tape only could be simplified considerably, as only the *Level Set, Base Cutoff, Suppr. Gain, and Sig. Compare* controls would be needed. The power supply as shown can easily handle two channels.

The noise level of the filter itself depends mostly on output amplifier A7. Of several units I tried, the noise level ranged from 62 to 68 dB below 0 VU.

A few tips on the mechanical aspects of copying records are in order here. The importance of good tracking cannot be overemphasized. More can be gained here than with any amount of electronic processing. Groove radius, depth, and angle were not standardized on early discs, and experimentation with tracking force and stylus size, if possible, may yield a considerable improvement in both noise and distortion. The playback stylus should, of course, ride on the sides of the groove. If it is too small it may ride the bottom of the groove and skate from side to side in a partially uncontrolled manner, creating severe distortion. If too large, it will ride high in the groove where it is more sensitive to surface blemishes. Also, larger styli cannot follow high-frequency modulation as well, especially on the inner record grooves. Elliptical styli are helpful on relatively wide-range 78s if the latter have not been damaged by previous playings.

Acoustic records (1925 and earlier) tend to have a larger groove, since with acoustic playback the mechanically-imparted stylus motion had to supply all the sound power. For these, a stylus of 4-mil (.004") radius may produce better results than the standard 3-mil size. Custom-made styli with a "truncated" tip (really a smooth transition from a 2- or 3-mil radius to about a 4-mil radius at the very tip) have been used to track the groove sides of 78s properly while avoiding contact with the bottom. (Truncated and other special styli are available from the International Observatory Instruments, 5401 Wakefield Drive, Nashville, Tenn. 37220). Although not a cure-all, these can give dramatic results on selected discs. A 2.5 mil stylus is best for most post-1946 transcriptions. Obviously, the pickup should have adequate lateral compliance and should produce no output for vertical motion. Incidentally, electrical recordings made before the mid-1940s are mostly recorded flat, that is, they have no high-frequency pre-emphasis, while later records have pre-emphasis of as much as 16 dB at 10 kHz.

Edison cylinders (160 rpm) and discs (80 rpm), some Pathe discs, and some early wax transcriptions are vertically modulated. Here the stylus does ride on the groove bottom, and the pickup should have only vertical response. This can be obtained (as can lateral-only response) from a suitably-phased stereo cartridge. Stylus radii of 4 to 10 mils are typical here; as always, experimentation is in order.

An article, outlining a number of techniques for obtaining good quality sound from early recordings was published in the May 1975 issue of our associated journal 'Hi-Fi Review'. Some back copies are still available from our subscription department for $1.00 each, including postage and packing.

FUTURE DEVELOPMENT

The experimenter may want to try to improve the performance of the circuit described. Of course, additional types of processing can be added, such as more effective click suppression at the filter input or multi-channel equalization at the output. These would be electrically independent of the noise filter, and beyond the scope of this article. However, there are some possibilities for improving the noise filter itself. Many of these, unfortunately, would require an incongruous increase in complexity and cost.

Sharper filter cutoffs give a marginal improvement on very noisy material, but setup adjustments become more critical. Dynamic high-pass (low-cut) filtering using a simple 6 dB/octave slope might be a reasonable addition. Since the noise-rejection frequency band of the low-pass dynamic filter should complement the noise spectrum of the signal, a statistical study of record and tape noise spectra might lead to a better shape for the bandwidth-control-signal separation filter of Fig. 7. The separation filter selector could be ganged with the pre-filter cutoff switch to eliminate one control knob. Perhaps a noticeable improvement could be realized by experimenting with the shape of the bandwidth control characteristic, Fig. 9. The attack time constant could be shortened by using a more elaborate filter at the precision detector output; this would improve the response to occasionally encountered wide-band transients.

An obviously desirable change would be to replace the FET bandwidth-control filter with one of the voltage-controlled state-variable types. This would eliminate the need for FET selection, but would increase the cost severalfold. It therefore appears that the original goal of high performance per dollar has been achieved, yielding a practical design which is within reach of the hobbyist.

References

1. Burwen, R.S., "A Dynamic Noise Filter," *J. Audio Eng. Soc.* 19, PP. 115-120, Feb., 1971.
2. Mori, T., "Designing Low-Frequency Active Filters," *Electro-Technology,* P.72, Jan. 1968.
3. Langford-Smith, F., Ed., "Reproduction From Records", *Radiotron Designer's Handbook* (Wireless Press, 1953), PP. 701-774.
4. Scott, H.H., "Dynamic Noise Suppressor," *Electronics,* PP. 96-1001, Dec., 1947.
5. Fletcher, H., "Loudness, Masking, and Their Relation to the Hearing Process and the Problem of Noise Measurement," *J. Acoust. Soc. Am.* 9, PP. 275-293, Apr., 1938.

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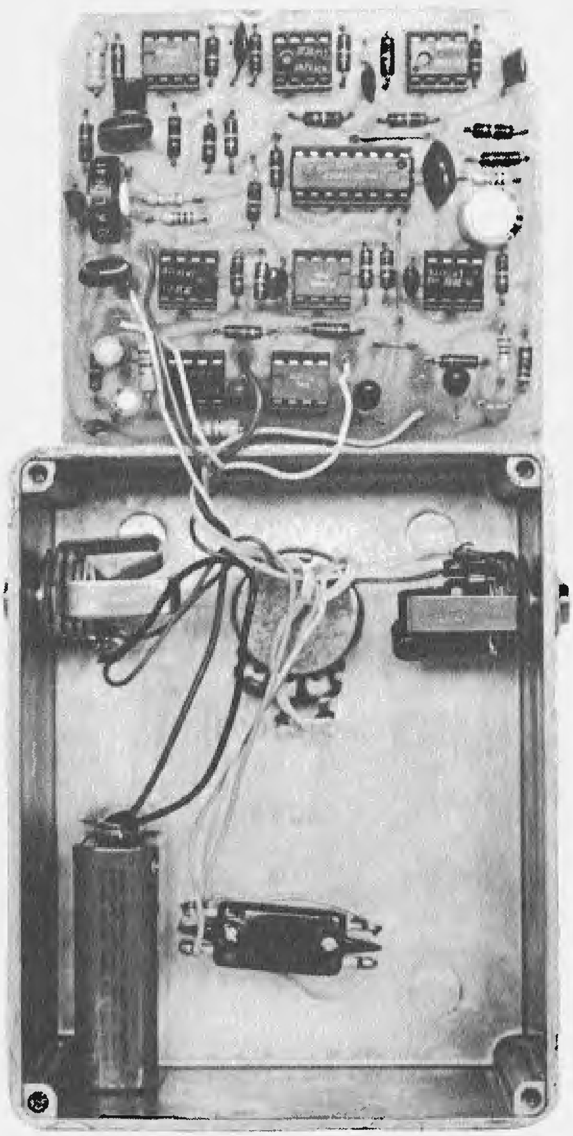
AUDIO PHASER

This six-stage phaser can make your electric guitar sound really spacey. And it costs less than thirty bucks to build.



THERE AREN'T MANY electronic music accessories that we haven't published as projects in ETI and this project will make the list even shorter.

Most musicians will know what a phaser sounds like and it is going to be very difficult for us to describe the effect to readers who don't know the sound. It really has to be heard to be appreciated.

The most dramatic effect, and the easiest to describe, is that caused by feeding white noise through a phaser. The sound is similar to the sound of surf, an 'atmospheric' whooshing sound. On recordings phaser effects can be heard on electric guitars, drums electric piano, and other instruments.

Technically the phaser acts as a filter — it phases out certain frequencies in the audio spectrum and over a period of a second or two these minima in the response curve sweep up and down the audio band. The response of the ETI phaser can be seen in Figure 3. Frequencies between 10 Hz and 4 kHz are present in varying proportions between 0 and 100% of the input signal level. As the values of the components in the phase-shift network change, the proportions of these frequencies will change as the response curve moves up and down the audio spectrum.

The unit we have designed is a six-stage phaser (there are six phase-shift networks in the phase-change path) which gives three minima in its response curve. It is built into a die-cast box so it can be used on stage by a guitarist. The only external control adjusts the speed, except for the foot-operated switch which puts the phaser in or out of circuit. The power is switched on by plugging the jack plugs into their sockets.

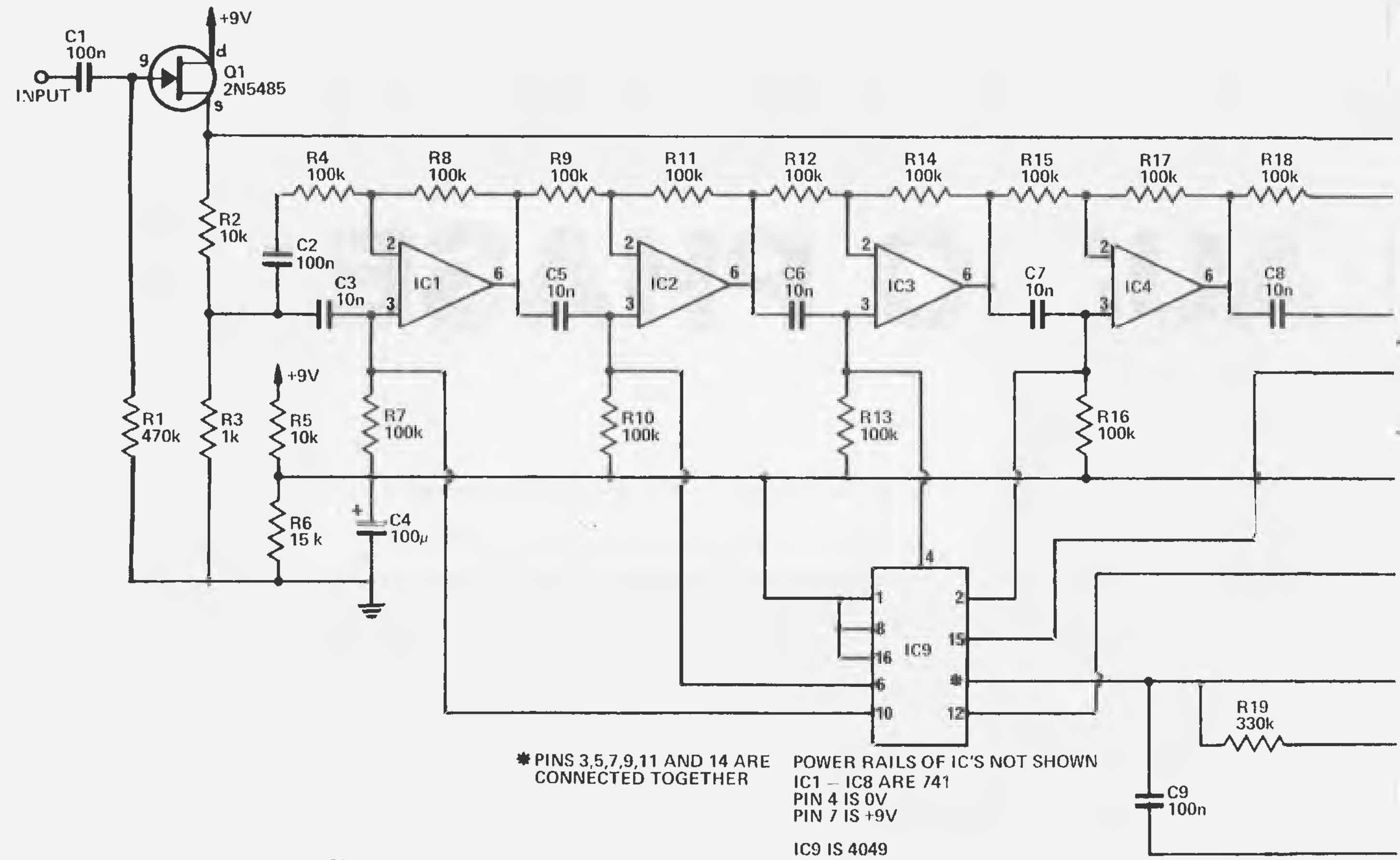


Fig 1 Circuit diagram for the Audio Phaser

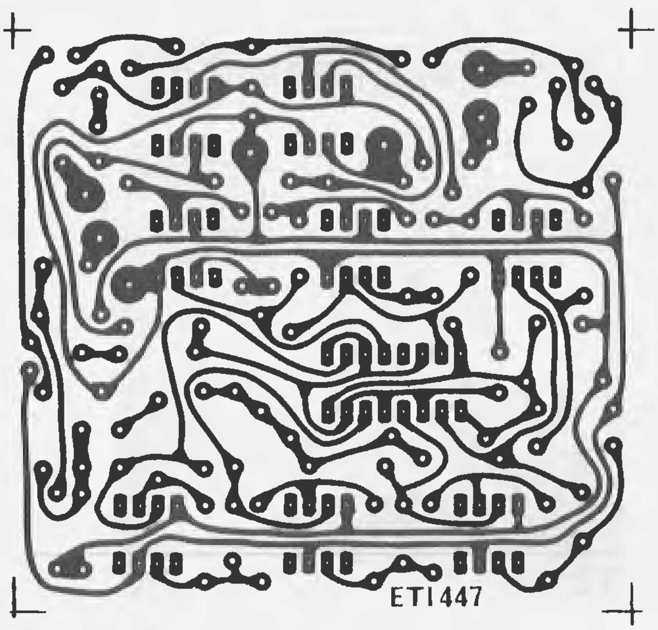


Fig 2 Printed-Circuit Layout. Full Size 81 x 76 mm.

Specification ETI 447 Phaser

Phase-shift stages	Six stages providing a maximum 1080 degrees phase-shift, and consequently three minima (see graph).
Frequency range	With 10n and 100k networks, minima at 40 Hz, 160 Hz, and 600 Hz. With 10n and 56k networks, minima at 70 Hz, 270 Hz and 1 kHz (as shown in Figure 3). With 10n and 10k networks, minima at 400 Hz, 1600 Hz and 60 kHz. In operation the resistive element of the phase-shift networks varies continuously and these minima sweep across the spectrum.
Input impedance	500k.
Input sensitivity	3 mV to 1 V.
Overall gain	unity.

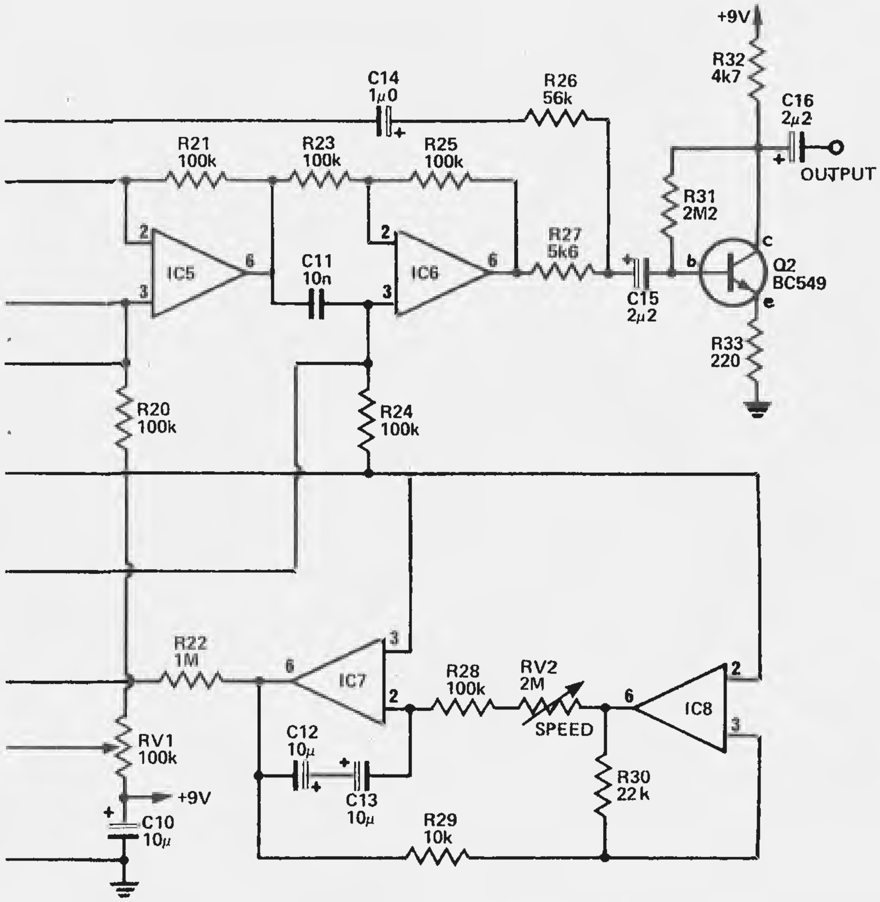
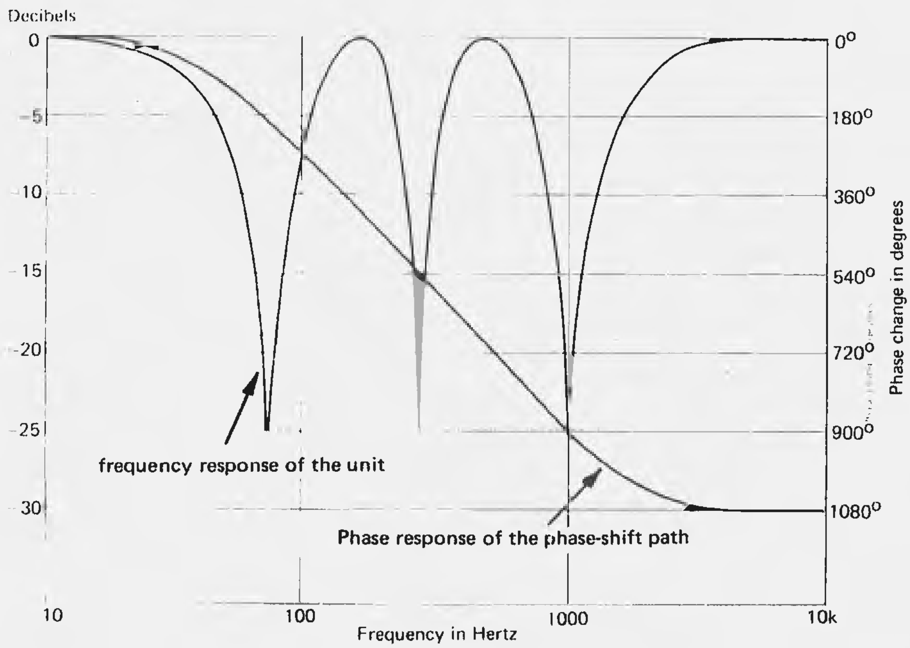


Fig 3 Frequency response of the unit when the phase shift networks have 56k effective resistance. As this value varies the response curve is moved up and down the frequency axis.



Construction

Apart from the pcb the box contains one pot, two jack sockets and a foot-operated switch, so construction is unlikely to be any problem. Use our design for the pcb pattern and insert the components according to the overlay drawing. IC sockets do not have to be used but a socket would spare the CMOS IC from the dangers of direct soldering.

First solder the low-profile components to the board, then the other components. When the case-mounted parts have been installed, wire up the board to these using sufficiently long leads to enable easy fault-finding, should this be necessary.

For stage use, the phaser needs properly protecting against physical shocks so we strongly recommend you use a die-cast box and wrap the pcb in foam sheeting rather than screwing it to the case. If the phaser is to be built into a mixer or an effects unit then housing is obviously less important.

Setting up

The best way to set up the phaser is to use a white noise source and then adjust the bias preset to give a continuous whooshing sound. If the bias is incorrectly set, the sound will be interrupted, it will not whoosh continuously.

If you do not have a white noise source use a signal high in harmonic content: electric guitar, crowd noise, FM hiss, etc.

We cannot teach you how to use the phaser, it is a special effect offered as an aid to creative musicians. It can produce weird effects with almost any audio source (it can, for example, simulate long-distance phonecalls or radio stations) and it is necessary to play certain styles of electric guitar and electric piano.

The phaser can be plugged into the echo send and echo return sockets of the ETI Master Mixer for use on any channel as desired.

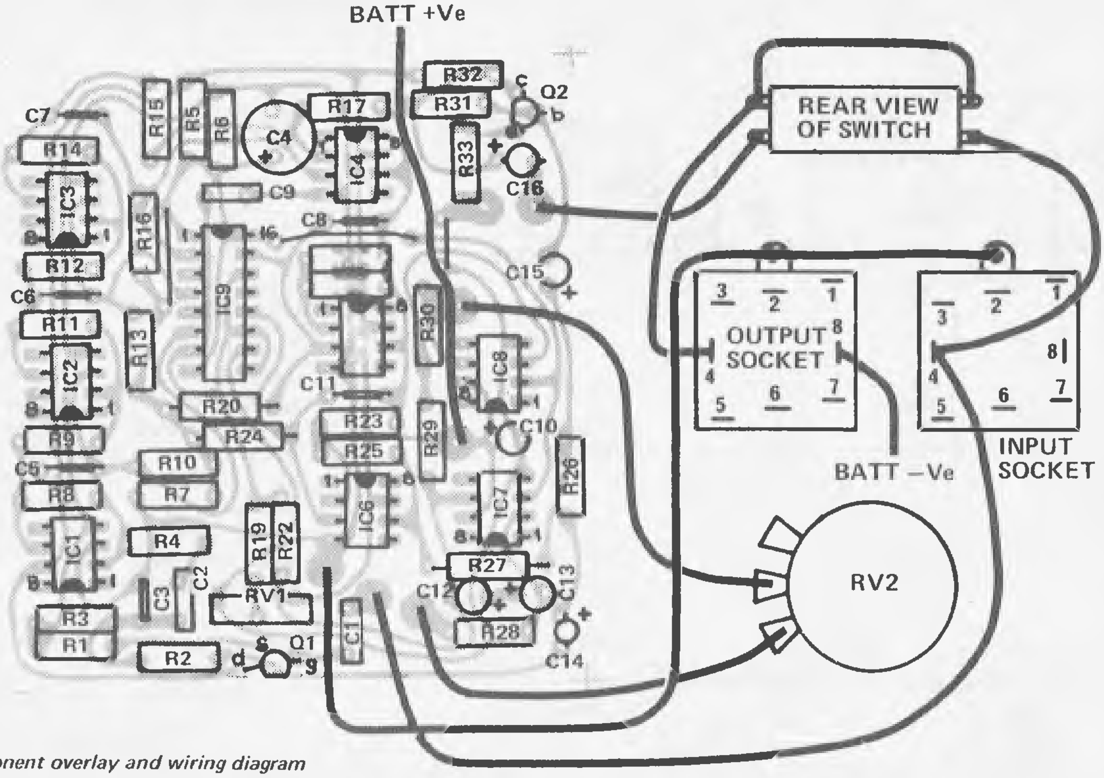


Fig 4 Component overlay and wiring diagram

Note:

The integrated circuit IC9 should not be a Philips or Signetics type. These have buffered outputs and therefore cannot be connected to obtain a FET as required in the Audio Phaser.

On the circuit diagram RV1 is shown connected between +9 volts and the junction of R5 and R6. On the printed-circuit board it is connected between +9 volts and the zero-volt line. This variation in connection does not affect operation of the phaser.

The phaser is sensitive to supply-voltage variations especially when using small batteries. Use a large battery, or use a 12 volt battery to feed a 9 volt zener regulator via a 220 ohm resistor.

Parts List ETI 447

Resistors all ½ W 5%

R1	470 k
R2	10 k
R3	1 k
R4	100 k
R5	10 k
R6	15 k
R7-R18	100 k
R19	330 k
R20,21	100 k
R22	1 M
R23-R25	100 k
R26	56 k
R27	5 k6
R28	100 k
R29	10 k
R30	22 k
R31	2 M2
R32	4 k7
R33	220

Potentiometers

RV1	100 k trim type
RV2	2 M log rotary

Capacitors

C1,2	100 n polyester
C3	10 n "
C4	100 µF 6 V electro
C5-C8	10 n polyester
C9	100 n "
C10	10 µF 25 V electro
C11	10 n polyester
C12,13	10 µF 25 V electro
C14	1 µF 25 V electro
C15,16	2 µ2 25 V electro

Semiconductors

Q1	2N5485 or similar
Q2	BC549 or similar
IC1-IC8	µA741 op-amp
IC9	4049 CMOS

Miscellaneous

PC Board ETI 447
Two stereo phone sockets
Switch — push on push off foot operated push button
Case to suit
9 V battery
Knob

ETI 447 — How it works

The input impedance of the phaser has to be high to prevent damping of the strings when used with an electric guitar. Loading caused by a low input impedance would stop the notes from sustaining properly. In the ETI phaser this is acheived by the high impedance buffer,Q1.

After the input buffer the signal is split along two paths, and the two parts do not meet again until they are mixed back together again at the junction of R26 and R27. One part of the signal undergoes phase-shift, via ICs 1 to 6, and the other part follows a direct path. Q2 amplifies the output to give an overall gain of unity.

The phase-shift is achieved in six identical RC networks; the overall shift being the sum of the shifts at each stage. IC9 varies the value of resistance in each stage, but we will first look at the operation with a fixed value, say 56k.

In this case each stage puts a 10n capacitor and 56k resistor across the signal. The waveform at the junction of these two components has to be of such phasing as to reconcile the perpendicular phasing of the waveforms across each component.

The signal fed into the op-amp undergoes a phase-shift, but the phase-shift is not the same for all frequencies. In the one stage the signal undergoes a change of 180 degrees at high frequencies and a negligible change at low frequencies. The curve of Figure 3 shows that there is little shift at 10 Hz and 1080° at 4 kHz (that is 180° at each stage: a total)$^{\circ}$ of 1080° from all six stages).

When all six stages are taken into account, frequencies from 10 Hz to 4 kHz have a continuous range of phase-shifts from 0 to 1080°.

Figure 3 also shows what happens when equal amplitudes of the two signals (from the direct and phase-shift paths) are mixed.

Because frequencies outside the range 10 Hz to 4 kHz are in phase the response is flat. In-phase mixing also occurs within this range at two places. These are at phase differences of 360° and 720°, in this case at 160 Hz and at 460 Hz.

The holes in the response are caused by out-of-phase mixing, as occurs when the phase differences are 180°, 540°, and 900°. With 10n and 56k in the phase-shift networks these minima occur at 70 Hz, 270 Hz, and 1 kHz.

The number of minima in the response is directly related to the number of phase-shift stages. Four stages would give a maximum phase shift of 720° and minima would then only occur at 180° and 540°. If you use eight stages another minimum will occur at 1260°, giving four in all.

The rest of the circuitry in the phaser is used to vary the resistance in the phase-shift networks to move the response curve of the phaser up and down the frequency axis. IC9 is effectively six sets of complementary FETs and the resistance of each can be controlled by applying a voltage onto its gate. Varying the gate voltage of IC9 causes the effective resistance of R7 to be shunted from 100k down to a few kilohms.

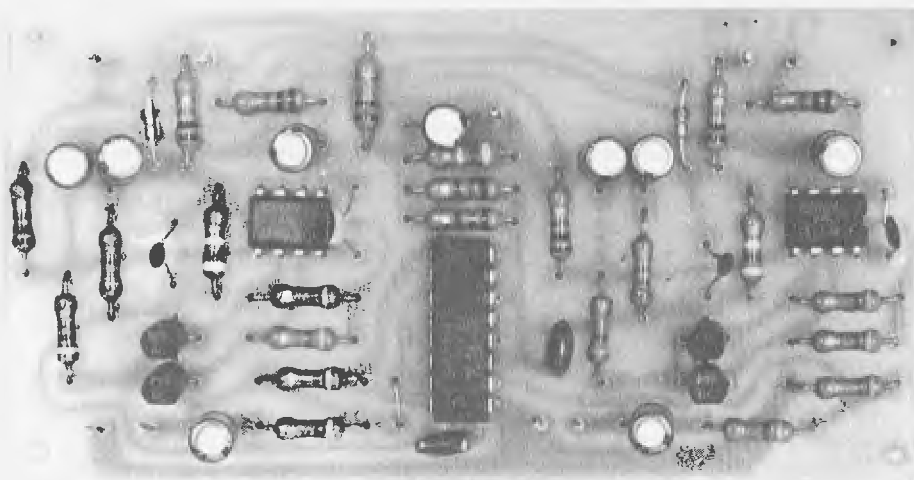
IC7 is an integrator and IC8 is a Schmitt trigger; together they make a triangle-wave oscillator. This triangle waveform gives a rising and falling voltage to the gates in IC9.The waveform has to be correctly biased to give the desired resistance change in each phase-shift stage. The bias voltage is set by RV1.

RV2 controls the speed of the triangle-wave oscillator to give periods ranging from a few seconds down to a tenth of a second or so.

The zero reference voltage for the op-amps is taken from the junction of R5 and R6, which is at half the supply voltage. This does away with the need for a split supply — a single 9 V battery is sufficient. The power is switched on and off by the jack socket. The foot-switch switches the phaser in and out of circuit.

AUDIO LIMITER

This simple but effective unit can be used as a limiter, automatic volume control or voltage controlled amplifier.



A LIMITER IS A FORM of compressor which operates only when the signal exceeds a certain predetermined level. For example signals which do not exceed say 80% of the predetermined maximum are not compressed at all and are amplified with their full dynamic range. For signals above the 80% level the limiter begins to operate and very large input signals are required to obtain the extra 20% of output.

Another use of a limiter is in the continuous-limit mode such that it acts as an automatic volume control (AVC). In this mode a 60 dB change in input level can be limited to say, a 6 dB change in output level.

Finally the limiter may also be used as a voltage controlled amplifier having a range of about 55 dB. A typical application of such a device would be a remote volume control. It should be noted, however, that although the transfer function of such a voltage-controlled amplifier is fairly sharp, two of them may not necessarily track perfectly due to differences in the FETs in the ICs. Thus on our prototype the difference between channels when used as a stereo volume control was up to 5 dB at some points with any given input.

Design Features

When FETs are used in voltage controlled amplifiers it is essential that the voltage across them is kept as low as possible if the distortion is also to be kept low. This means that

Specification ETI 446

Input voltage range	**1 mV – 10 V**
Frequency response	**± 3 dB 10 Hz – 20 kHz**
Limiting point set by R2/16	**3mV**
Equivalent signal-to-noise ratio	**70 dB re 1 V out**
Distortion	**see graph**
Input impedance	**47 k**
Maximum gain	
R2/16 = 4k7	**26 dB**
R2/16 = 47k	**40 dB**
Maximum attenuation as voltage controlled amplifier	**55 dB**
Supply voltage	**± 8 V to ± 16 V dc at 5 mA**

the FET must be used as an attenuator where the voltage across the FET can be kept low irrespective of input voltage. The most suitable type of FET for this purpose is the enhancement-mode device but these are not readily available. The commonly available types are junction FETs which unfortunately require a negative voltage to turn them off. However, there is a suitable alternative, the 4049 CMOS IC which contains six inverting buffers. By suitable interconnection the IC may be made to provide six enhancement-mode FETs and this is the approach we decided to use.

To restore the signal level an amplifier is required and originally we intended to use the LM382 but, because of cost and availability considerations, we finally decided to use an LM301 or 741 operational amplifier together with a transistor pair at the front end. The noise performance of this arrangement was found to be as good as the LM382's and supply voltage to be less critical (although a dual supply is required). If only a single-ended supply is available then a 382 may be used, although a different board layout would be required.

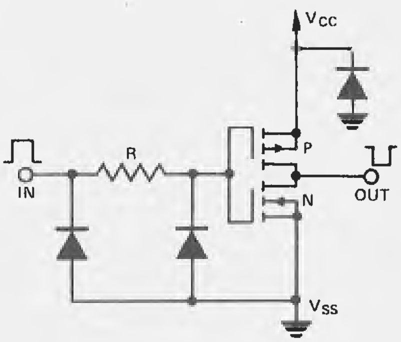


Fig. 6 Internal circuit diagram of one of the six inverter stages in the CMOS 4049 IC

USES OF A LIMITER

Peak Limiting. In this mode only signals above 85% of maximum level are attenuated. This is useful for preventing amplifier clipping (for pop groups or other live shows) which gives rise to objectionable distortion. It may also be used when tape recording the same type of programme material as above, to prevent the tape being saturated, which again would give rise to distortion.

AVC. In this mode, the limiter is used typically to drastically reduce the dynamic range of a programme being recorded. For example, when recording a lecture the 60dB dynamic range of lecture room speech may be compressed to 6dB.

Voltage Controlled Amplifier. As a voltage-controlled amplifier the unit lends itself to a variety of remote or automatic control applications. For example, it may be used as a remote control for stereo amplifier volume. Alternatively, it may be adjusted to increase car radio volume as ambient noise level rises.

Special Effects. The limiter may also be used to modify the sound of musical instruments. For example, such a limiter is often used to eliminate the attack transient on a bass guitar to give a smoother mellower sound.

The uses of such a circuit are wide indeed, and we are sure our readers will think of many more applications for this interesting circuit.

Construction

Although a printed-circuit board is not essential it certainly makes construction very much easier. Before assembly decide whether a limiter or an AVC is required as the values of R2 and R16 will vary accordingly. Use 47k for R2 and R16 in the AVC mode and in limit mode, depending on limit point, between 470 and 4k7. The transistor type specified is available from a number of different manufacturers but pin connections are different — the overlay shows connections for the Philips type. If a different brand is used the transistor should be reversed (emitter and collector interchanged). The overlay also shows the arrangement for using the LM301 ICs — these may be directly replaced by 741s simply by omitting the 33 pF capacitors.

Although the CMOS ICs 4449 and 4009 are electrically similar to the 4049 and are interchangeable with it when the devices are used as hex-inverters, they cannot be used as replacements in this circuit. The 4049 must be used. The 4449 and 4009 have different circuitry and will not work in this mode.

As this unit will normally be used in association with another piece of equipment, and most likely built in to it, a case has not been described. When installing the unit make sure that the input cables are coaxial or shielded cable — outputs are not important and can be normal hookup wire.

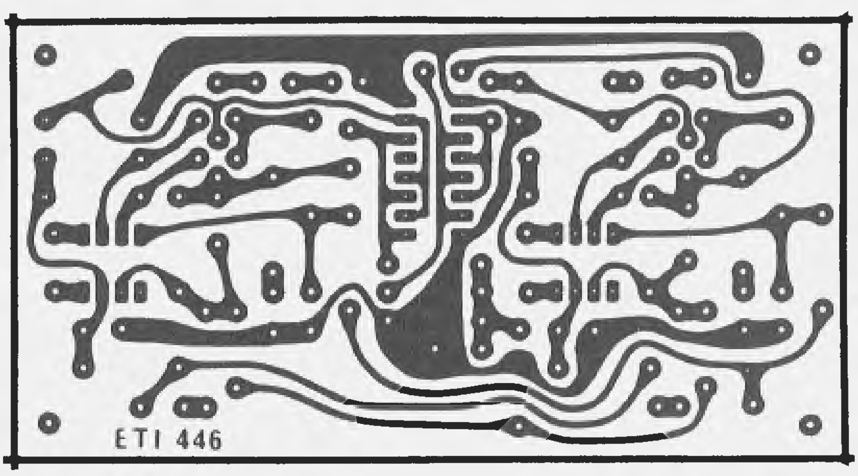
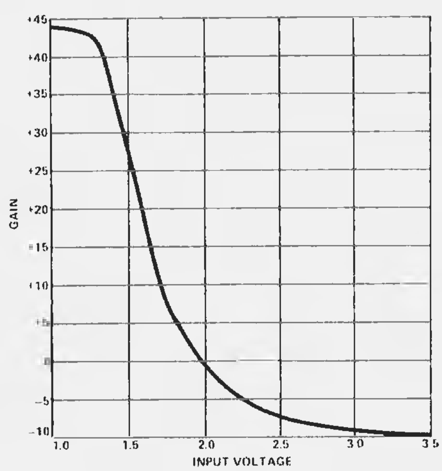


Fig. 5. Printed-Circuit layout for the limiter. Full size 58 mm x 110 mm.

Fig. 4 Gain versus control voltage with R2 = 47k



AUDIO LIMITER

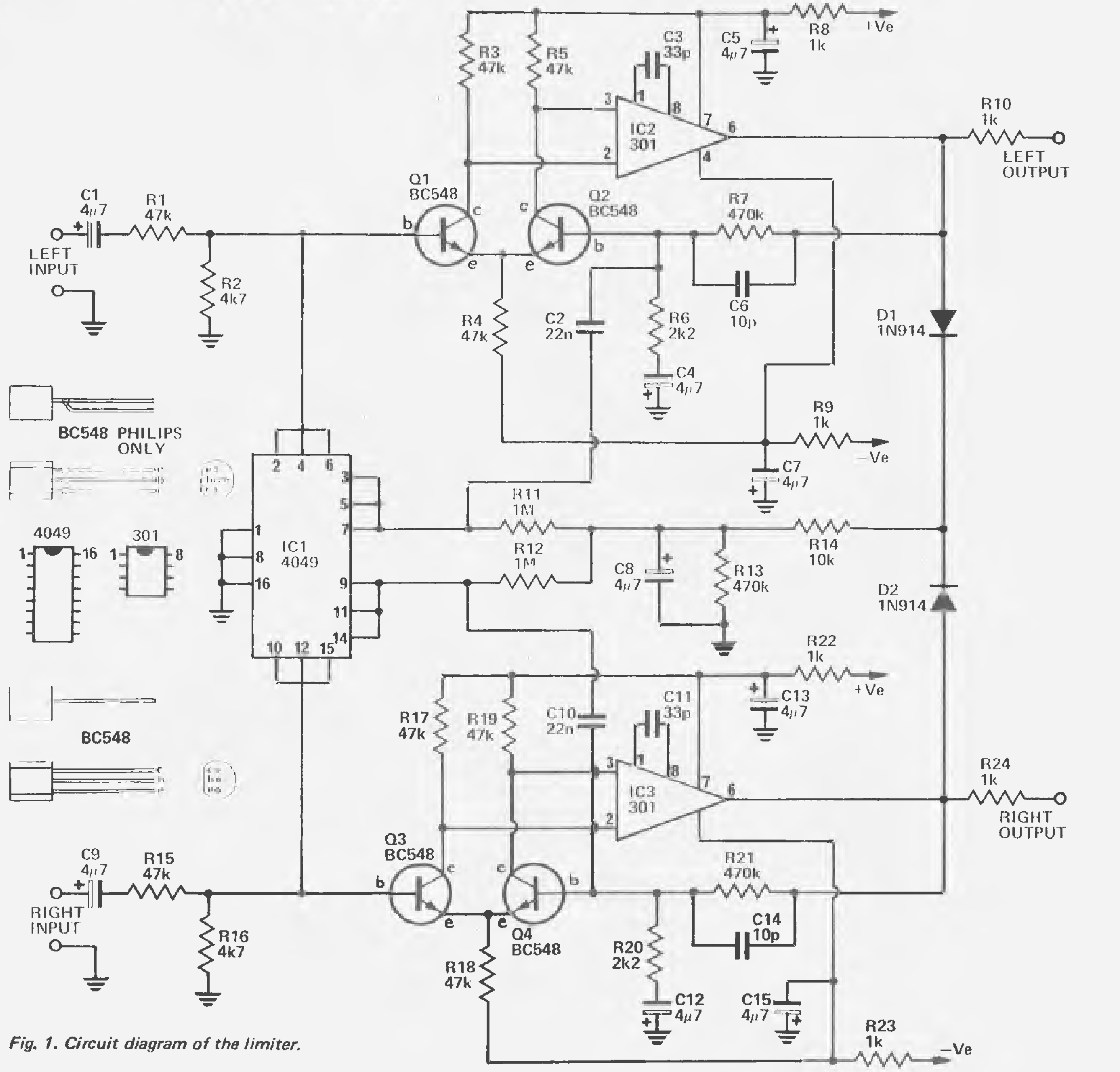


Fig. 1. Circuit diagram of the limiter.

How it works ETI-446

The circuit basically consists of a voltage-controlled attenuator followed by a low-noise amplifier with a gain of 46 dB. The output of this amplifier is rectified to generate a dc voltage which is used to control the attenuator.

The variable element in the attenuator is an enhancement mode FET. This is made from a CMOS hex-inverter IC, the 4049, by special interconnection. The difference between enhancement mode FETs and the normally available depletion-mode junction FETs is as follows: The enhancement mode FET has a high resistance between source and drain when the gate is at zero volts, but this decreases as the gate is taken more positive. A JFET (N type) is hard-on with the gate at zero volts and turns off as the voltage is taken negative.

The amplifier is required to have high open-loop gain and have fairly low noise. The gain requirement is provided by an LM301 operational amplifier and the low-noise requirement by a pair of transistors (connected as a differential pair) placed before the operational amplifier. The gain is set, by the combination of resistors R6 and R7, to 215 (or 46 dB). The lower 3 dB point is set at 15 Hz by C4 and R6 whilst the upper 3 dB point is set at 33 kHz by C6 and R7.

The outputs of both channels are summed and rectified by diodes D1 and D2 to charge C8 via R14. The voltage on C8 is coupled to the gate of the FETs (three in parallel on each channel) via R11 and R12.

As the input voltage increases the output also tends to increase and voltage on capacitor C8 also increases and this increase is applied back to the gates of the FETs. This reduces

PARTS LIST ETI 446

Resistors

R1	47k	½ W	5%
R2	4k7	"	"
R3-R5	47k	"	"
R6	2k2	"	"
R7	470k	"	"
R8-R10	1k	"	"
R11,12	1M	"	"
R13	470k	"	"
R14	10k	"	"
R15	47k	"	"
R16	4k7	"	"
R17-R19	47k	"	"
R20	2k2	"	"
R21	470k	"	"
R22-R24	1k	"	"

Capacitors

C1	4µ7 25 V electro
C2	22n polyester
C3	33p ceramic
C4,5	4µ7 25 V electro
C6	10p ceramic
C7-C9	4µ7 25 V electro
C10	22n polyester
C11	33p ceramic
C12,13	4µ7 25 V electro
C14	10p ceramic
C15	4µ7 25 V electro

Semiconductors

Q1-Q4 Transistors BC548
D1,2 Diode 1N914
IC1 Integrated circuit 4049 *
IC2,3 " " LM301

Miscellaneous

PC board ETI 446
9 PC board pins

**Do NOT substitute a 4009 or 4449 as the input protection is different. Nor should a Philips or Signetics type be used as these have a buffet output and cannot therefore be connected for use in the linear mode required for this project.*

the resistance of the FETs and thus increases the attenuation, tending to prevent the output from changing as much as the input does.

With all FETs the resistance changes with applied voltage and this gives rise to distortion. However by modulating the gate voltage with a signal equivalent to the voltage across the FETs the distortion is greatly reduced (3.5% down to 0.8%).

The attack and release times can be adjusted by varying R14 for attack and R13 for release.

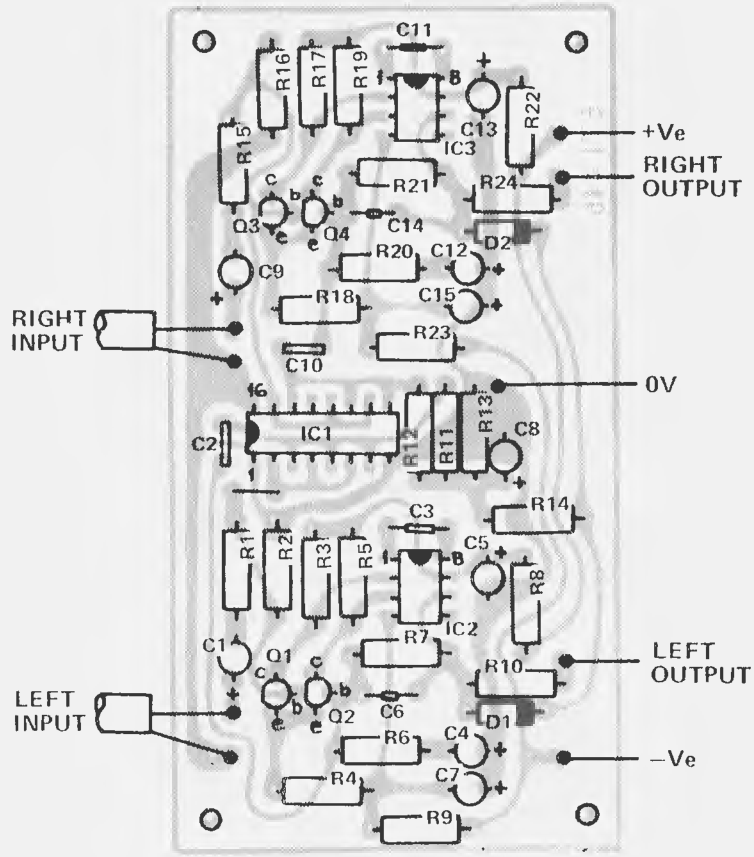
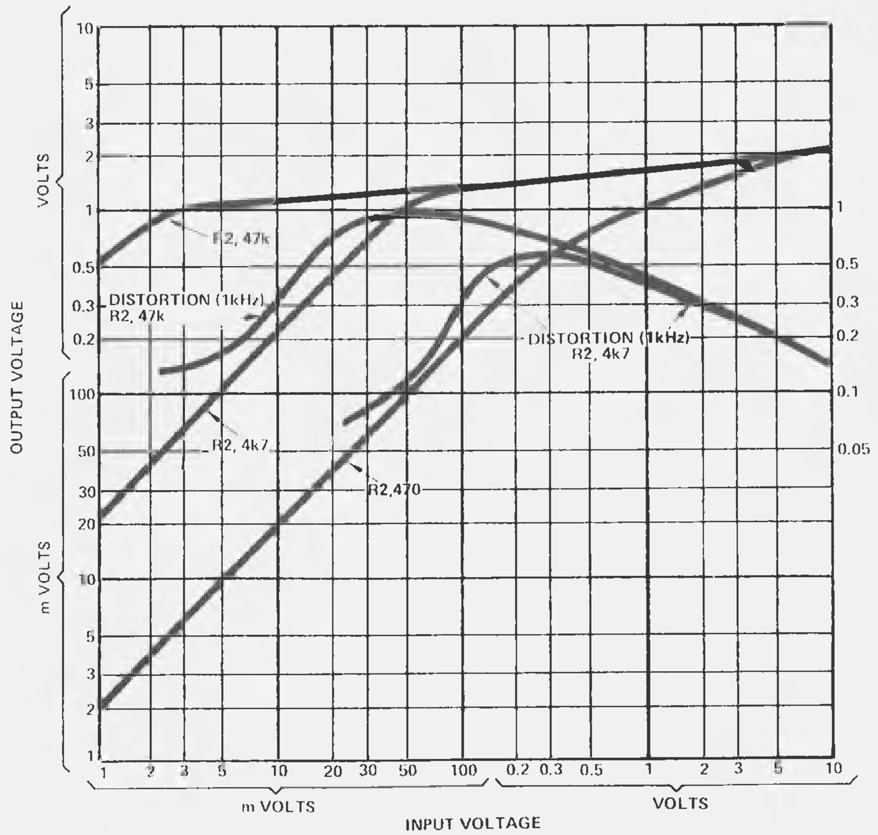


Fig. 2. Component overlay.

Fig. 3 Input versus output voltage for various values of R2 (and R16) Distortion at 1kHz for R2=4K7 and R2=47K are also shown.



SELECTA-GAME

with on-screen scoring and sound effects

* tennis
* soccer
* squash
* practice
* optional rifle

This low-cost yet sophisticated TV game contains just one main IC plus a handful of other components yet out-performs virtually all other units currently on the market.

AT THE TIME WHEN TV games first appeared in Australia they retailed for around a hundred dollars and had fairly limited capabilities. Many of our readers requested a TV game project but our investigation showed that 20 to 30 CMOS ICs would be required. As the circuit is quite complex we felt that the chances of a hobbyist building such a unit without problems were small, and any problems encountered would have been likely to be beyond solution with the equipment and knowledge available to the average constructor. We therefore decided not to do the project until single-chip TV game ICs became available. We knew that these chips were being developed and that they would make the project much simpler from the constructional point of view.

This project is based on such a single-chip device type AY-3-8500 from the General Instrument Corporation. The chip offers a choice of six games together with on-screen scoring and sound effects. The games are tennis, soccer, squash, practice and two rifle games. The rifle games required a 'rifle' which has additional circuitry built into it. On page 50 we describe the circuitry of a gun available from Dick Smith which can be used with this project.

Some additional circuitry, including two extra ICs, is required to build the game but the complexity of the complete circuit is still greatly reduced by the use of this particular IC. In addition, the chip, although expensive, does allow the cost of the unit to be reduced considerably even though its performance is superior to many other games on the market.

Construction

The TV game employs some VHF circuitry which demands correct lay out if proper operation is to be obtained. For this reason the game should only be built onto the printed-circuit board specified.

Commence construction by installing the seven tinned-copper wire links and then the low-height components (resistors, diodes, etc). Next install the capacitors and the transistors. ICs 2 and 3 are CMOS devices and should only be removed from their protective packing when you are ready to install them. Handle them as little as possible and when inserted solder the power supply pins (7 and 14) first. The main IC is expensive and it is therefore recommended (but not essential) that a 28-pin IC socket be used to mount it.

The coils L2 and L3 should now be constructed as detailed in Table 1 and then soldered into position making sure that L2 is oriented correctly.

The rotary switch may now be mounted in the following manner: First solder 25 mm lengths of tinned-copper to each of the switch pins (14 in all). Now orientate the switch correctly and feed the wires through the respective holes in the printed-circuit board, press the switch down onto the board and solder all the wires to the tracks of the board.

Now prepare the push buttons, the 5-pin DIN socket and the phono socket by soldering 40 mm lengths of tinned-copper to each of the terminals. Feed the wires through the respective holes in the printed-circuit board but do not solder just yet.

The slide switches should also be prepared in the following manner: Cut 60 mm lengths of 20 gauge BS tinned-copper wire (largest gauge that will fit through the switch holes) and thread them through the holes in the switch pins so that pairs of poles are linked together. Centre the wires in the lugs and then solder them to the lugs. Now bend the wires down on either side and insert them in the holes provided in the printed-circuit board but do not solder at this stage.

Fit the front panel to the rotary switch (use a spacer washer) making sure that the board is square to the front panel and that there is enough clearance for the RF coil and the shield which have yet to be fitted. Attach the phono socket, the DIN socket and the push buttons to the front panel and then solder their leads to the board. Push the slide switches up against the front panel, line the switches up with the openings in the front panel and, making sure that the switch doesn't move, solder the leads to the board.

Now remove the front panel and

fit the 75-ohm output coax and the coax for the bats to the printed-circuit board. Feed the bat cables through rubber grommets in the front panel after first tying knots in them to prevent them being pulled through accidentally. Alternatively 3.5 mm jacks may be installed on the front panel for the bat outputs and the cables fitted with plugs so that they can be unplugged when the game is not being used.

Add the battery leads and connect the speaker by means of 150-mm long wires. Check all wiring and solder joints before fitting the main IC to its socket.

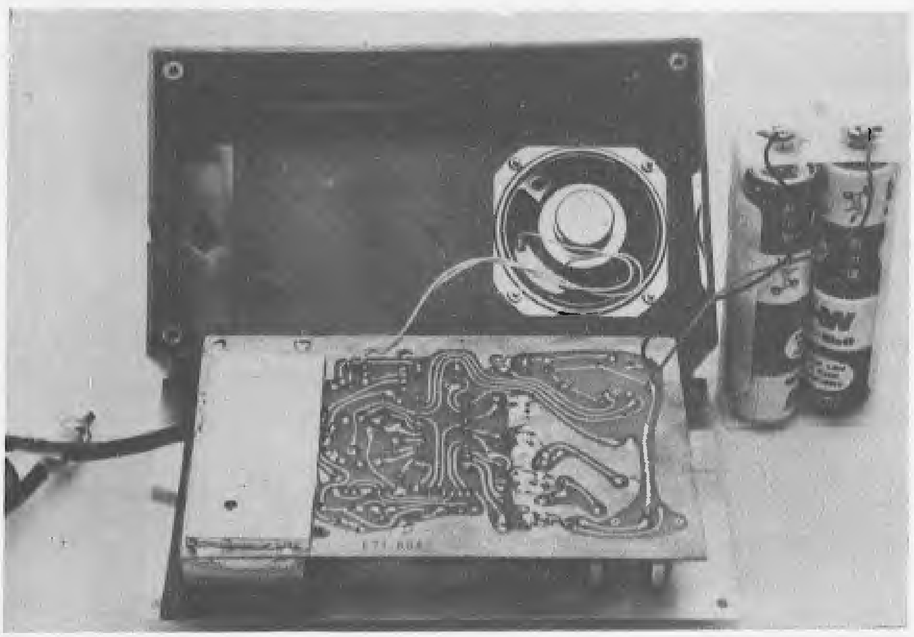
Before the shields for the RF stage are fitted the unit should be connected to a TV set and aligned and checked as detailed in the alignment section.

After alignment is satisfactorily completed fit the component-side shield using four short lengths of tinned-copper wire and then fit the copper-side shield by simply soldering it to the copper earth plane in four or five places. Make sure that the shields do not touch any other tracks, leads or components which would cause a short.

The alignment of the unit may now be peaked up if required. The front panel is normally at +7.5V due to the connections to the phono sockets and the shield is at 0V. Some plastic insulation tape should be used over the top of the shield or on the front panel to prevent shorting. Now fit the front panel and mount the assembly in the box. The batteries and speaker should be fitted into the bottom of the box under the printed-circuit board. Holes should be drilled in the box under the speaker to act as a grill to let out the sound from the speaker.

We initially used four "C" size batteries for power as the unit will work from about 5 to 8 volts. However to increase battery life 5 cells of either "C" or "AA" size should preferably be used.

If an external power unit is used either 6 or 7.5 volts dc will operate the unit and the 3.5 mm phone jack used should be used with the +Ve lead on the common terminal.



Alignment

Switch the TV set to channel 6 (5 or 7 could alternatively be used if channel 6 is used in your area), connect the TV game to the antenna input of the set and switch both units on.

Press the reset button on the game and tune coil L2 until the set appears to be receiving the signal. (At this time the picture may appear to be just a series of dots). Adjust the trimmer capacitor CV1 until the picture locks. Then it may be necessary to readjust L2 for the best picture.

When performing these adjustments it is best to use non-metallic tools so that the tuning point does not alter when the tool is removed.

SELECTA-GAME

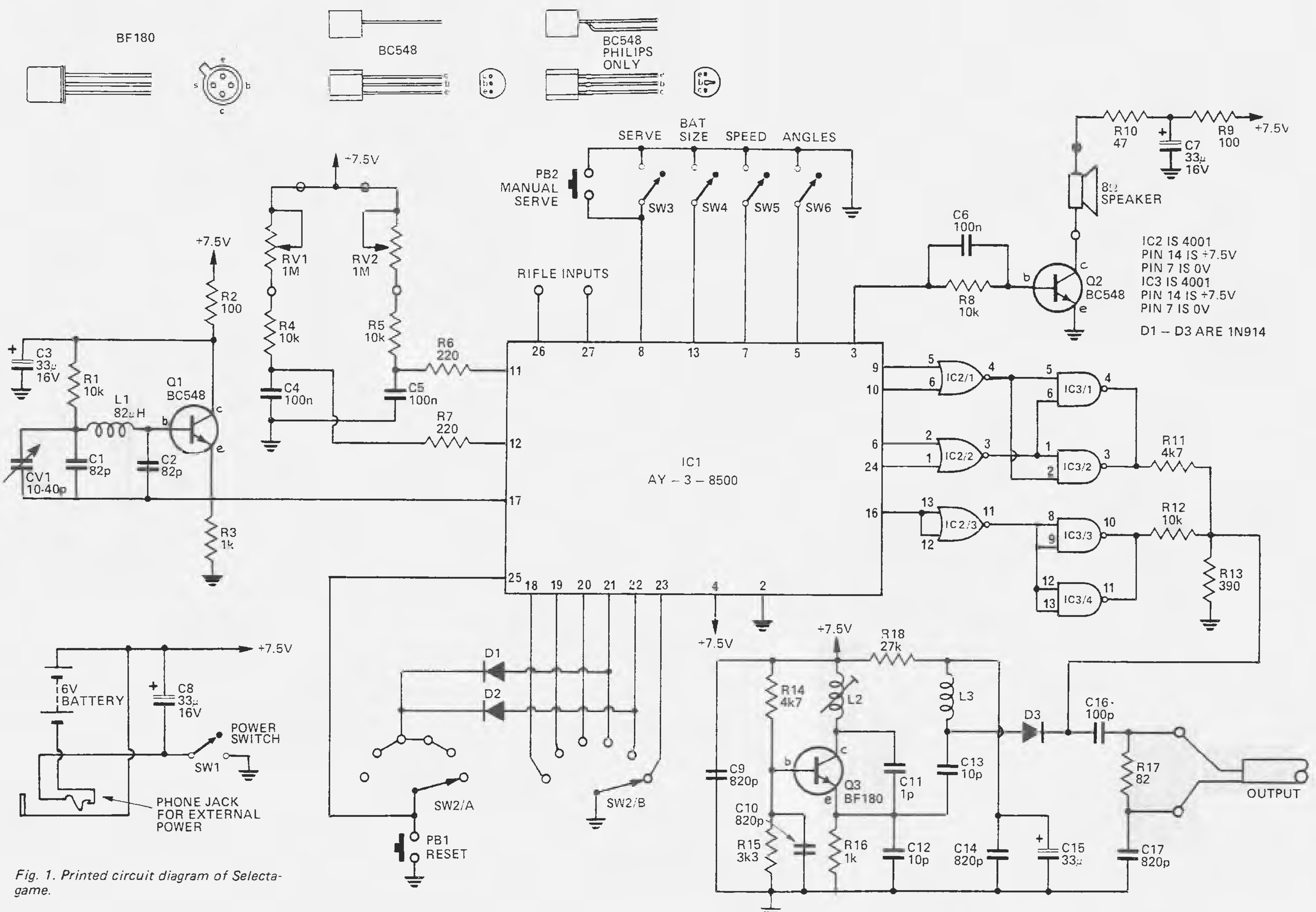


Fig. 1. Printed circuit diagram of Selecta-game.

How It Works — ETI 804.

Unfortunately the manufacturers don't give much information on how the main IC works — we are only told how to use it. The chip is obviously a digital IC (because there are two ball speeds, the rebound angles are defined and there is no provision for variable speed or bounce).

A 2 MHz oscillator is required for the chip to derive the synchronising pulses required for line and frame synchronisation of the TV set. This oscillator is provided by Q1 and its associated components with CV1 providing calibration.

The bats are simply one megohm potentiometers connected as variable resistors which effectively vary the charging time of capacitors C4 and C5. The capacitors C4 and C5 are discharged by the chip at each frame sync pulse and the time taken to charge again (as set by the bat pot setting) determines the vertical position of the bats on the screen. The bat size, ball speed, deflection angles and serve are simply selected by connecting the appropriate pin of the IC to '0' volts.

Outputs from the chip are left and right bat, sync, ball, score and sound — all on separate pins. The bats, ball and score outputs are combined by IC2/1,2 and IC3/1,2 to produce a composite video signal. The sync pulse is buffered by IC2/3 and IC3/3,4. The sync and information pulses are then added by R11, 12 and 13. The sound output is buffered by Q2 to provide the power necessary to drive the speaker.

So that the game may be fed into the antenna terminals of a TV receiver the video signal must be modulated onto an RF oscillator tuned to the desired channel (176 MHz for channel 6). Transistor Q3 and its associated components form the required oscillator. The oscillator is then modulated with the composite video by means of the diode modulator D3.

The oscillator and the modulator are screened by means of shields to prevent the RF from causing interference to other TV sets (and to prevent other TV sets from interfering with the game). These shields also minimise detuning effects when the hand is brought close to the oscillator.

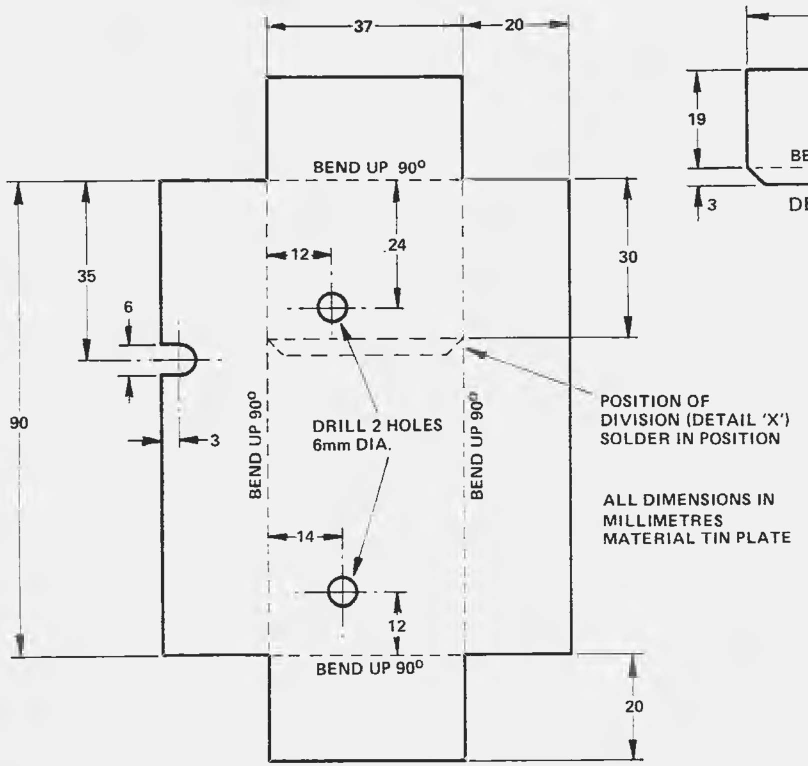


Fig. 2. Dimensions of shield on component side.

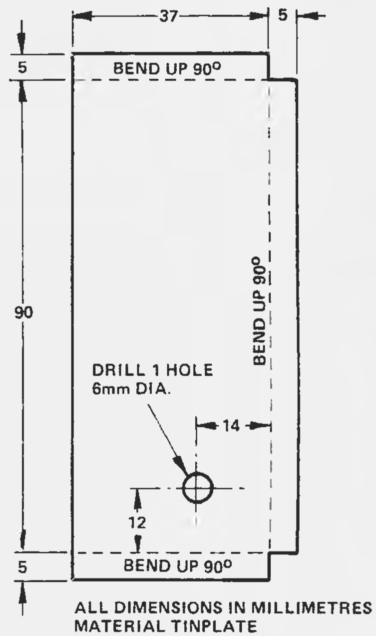
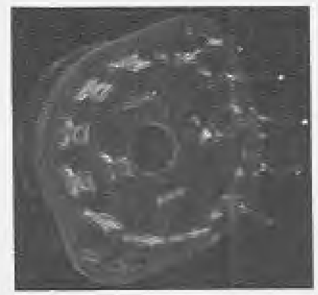
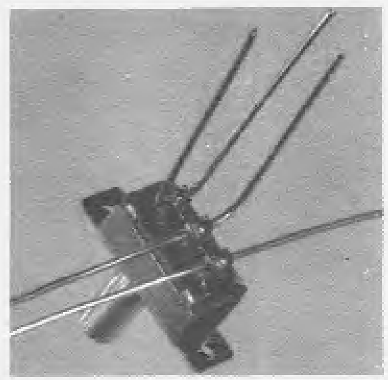


Fig. 3. Dimensions of shield on copper side.





Photographs showing wires attached to switches before installation.

Project 804

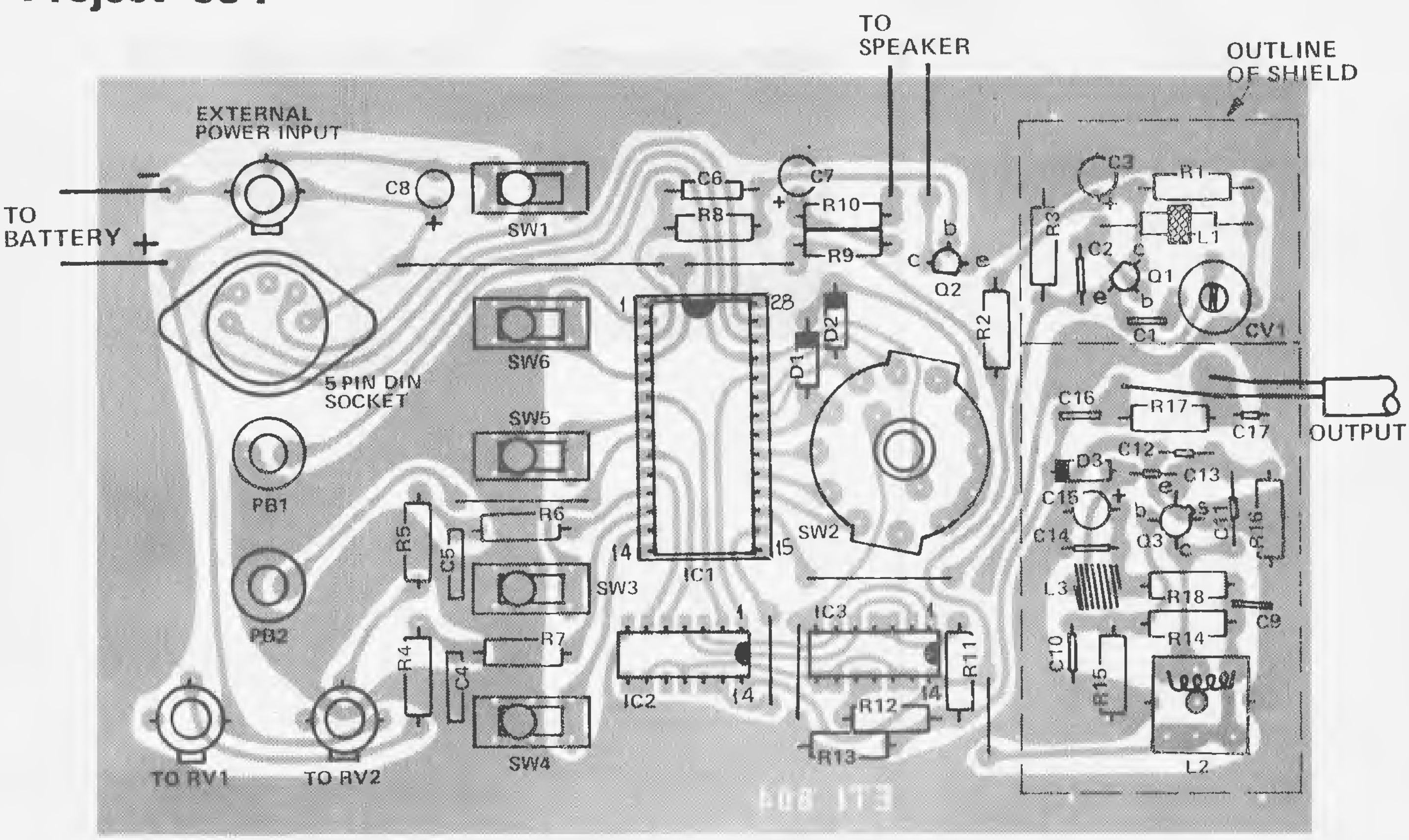


Fig. 4 Component overlay of Selecta-game.

PARTS LIST ETI 804

Resistors all ¼w 5%

R1	10 k
R2	100
R3	1 k
R4,5	10 k
R6,7	220
R8	10 k
R9	100
R10	47
R11	4 k 7
R12	10 k
R13	390
R14	4 k 7
R15	3 k 3
R16	1 k
R17	82
R18	27k

Potentiometers

RV1,2	1M lin rotary

NOTE: see modification Fig. 2 page 51.

Capacitors

C1,2	82 p ceramic
C3	33 μ 16 v electro
C4,5,6	100 n polyester
C7,8	33 μ 16 v electro
C9,10	820 p ceramic
C11	1p0 ceramic
C12,13	10 p ceramic
C14	820 p ceramic
C15	33 μ 16 v electro
C16	100 p ceramic
C17	820 p ceramic

Variable capacitor

CV1	10-40p

Transistors

Q1,2	BC548 or similar
Q3	BF180

Diodes

D1-D3	1N914

Integrated Circuits

IC1	AY-3-8500
IC2	4001 (CMOS)
IC3	4011 (CMOS)

Inductors

L1	82 μ H RF choke
L2	See table 1
L3	See table 1

Miscellaneous

PC board eti 804
2 pole 6 position switch
Five slide switches
8 ohm speaker
3.5 mm phone socket
5 pin DIN socket
Two miniature push buttons
Three knobs
One large box 196mm x 113mm
Two small boxes 83mm x 54mm
Single "C" size battery holderder
28 pin IC socket

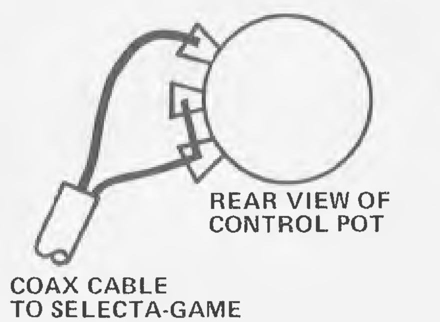


Fig. 5. Diagram showing wiring of control pot.

TABLE 1 ETI 804

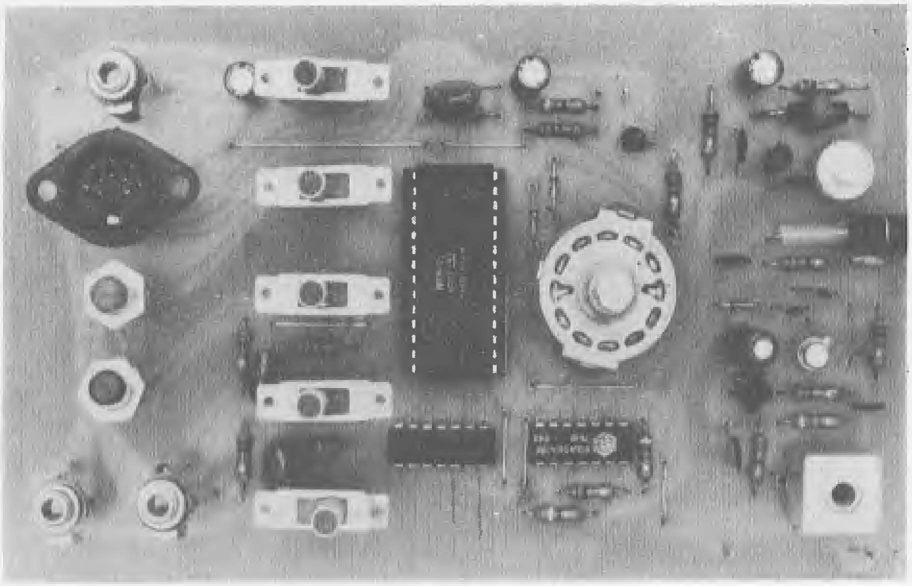
Winding details of coils L2 & L3

L2

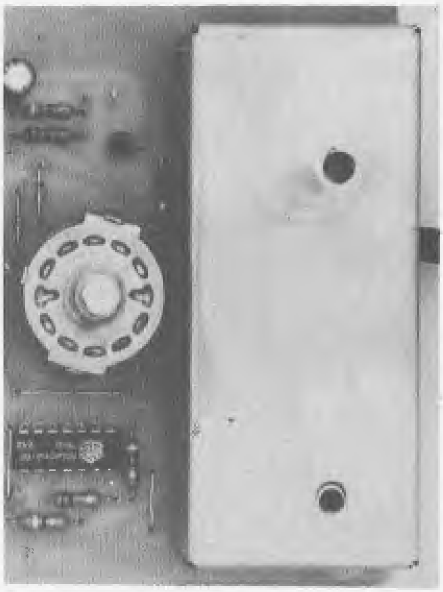
Former 5mm	Neosid 722/i
6 pin base	Neosid 5027/6 PLB
Can	Neosid 7100
Slug	Neosid 4 x 0.5 x 10 F29

Winding 4 turns close wound 24 B&S

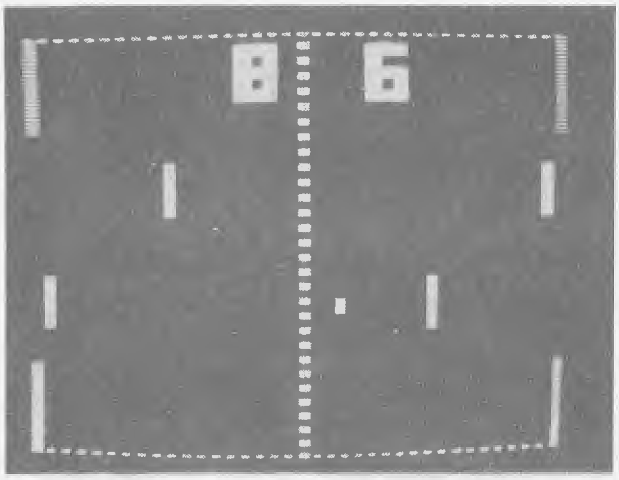
L3
6 turns 24 B&S wire close wound about 5mm diameter, air core. (wind on a former, ie a knitting needle or drill, then remove former)



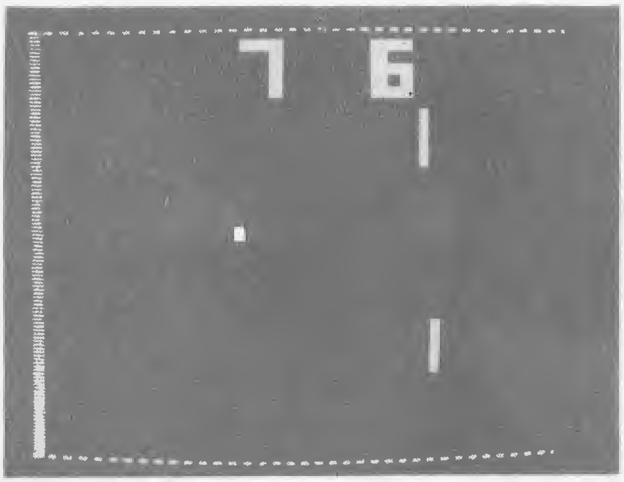
Photograph of completed board less shield.



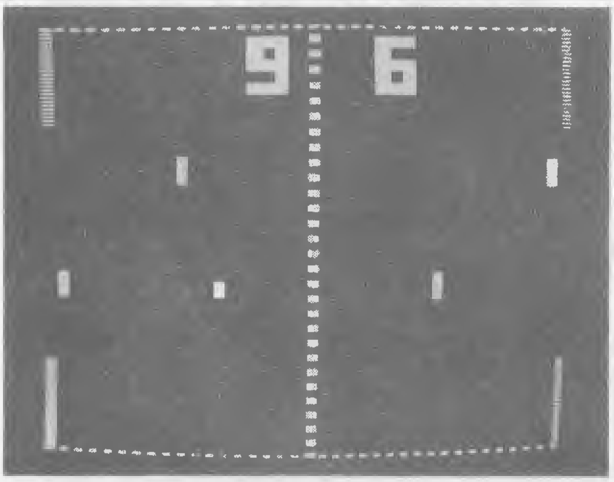
Photograph showing shield fitted. Note two adjustment holes



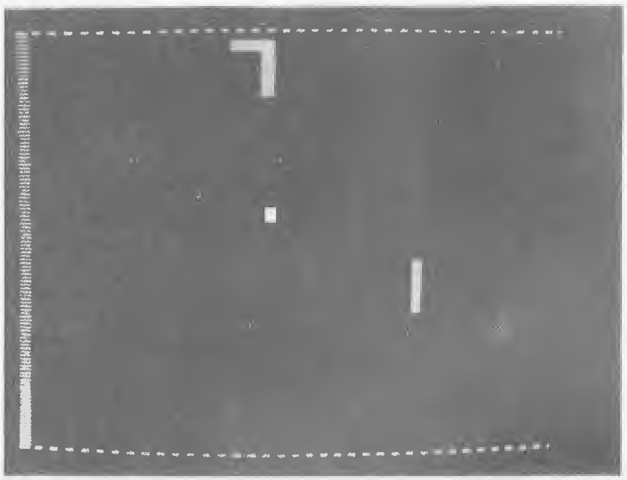
Soccer



Squash



Soccer with small bats



Practice

These photographs show some of the games that can be played.

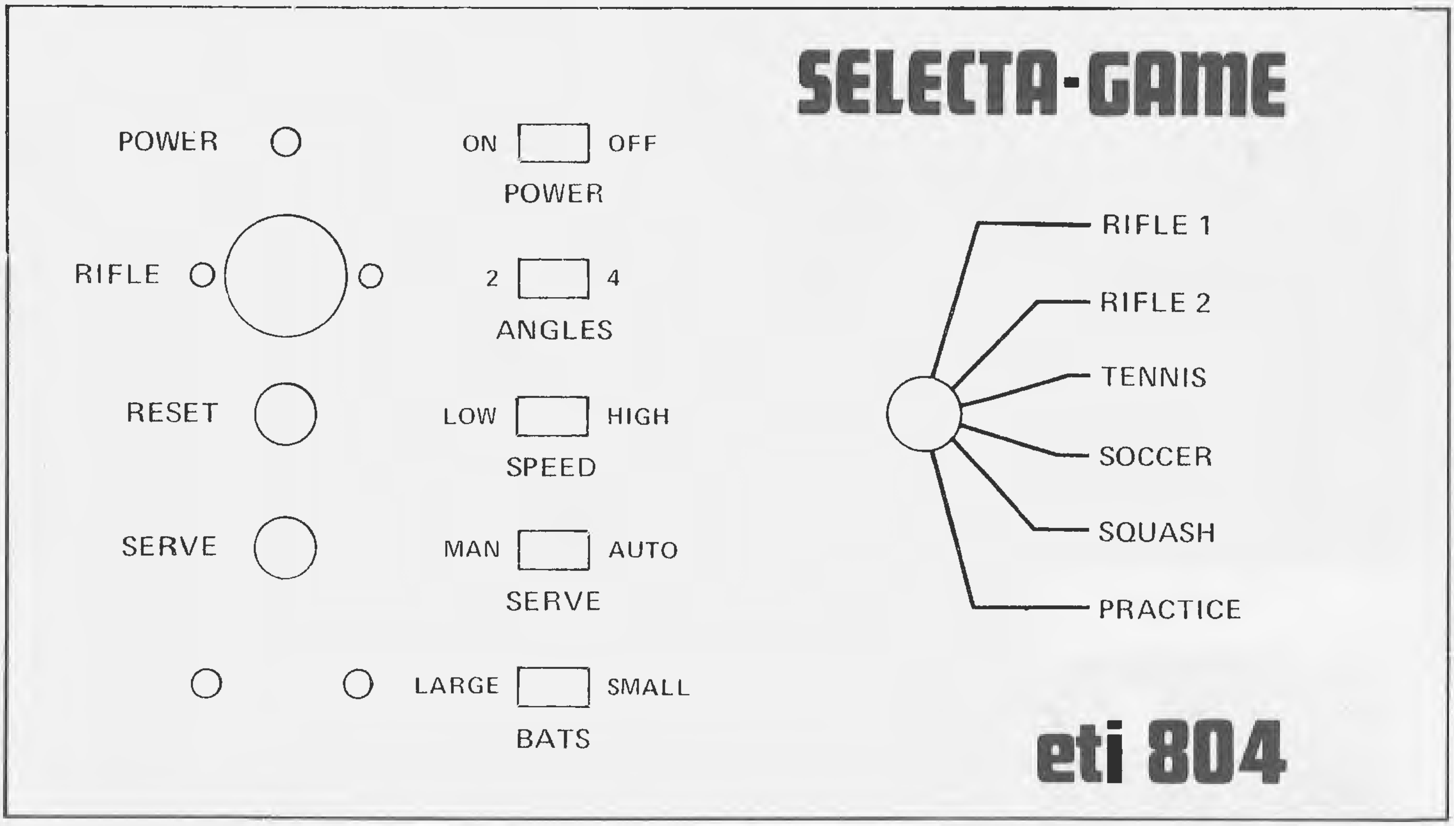


Fig. 6. Front panel layout. Full size 190mm x 107mm.

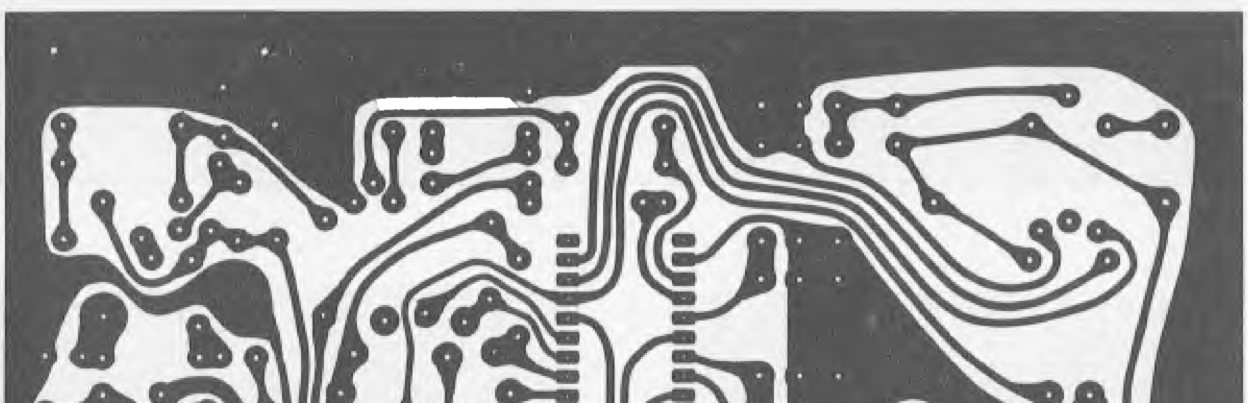


Fig 7. Printed-circuit layout. Full size 163mm x 102mm.

THE GAMES

1) Practice: The ball reflects off the end wall and the side walls — the player has to stop it exiting the screen on the right-hand side. This game is an electronic version of hand-ball or squash with only one player.

2) Squash: This game is like the practice game but now there are two players who take turns in hitting the ball. The bat has no effect on the ball when it's your opponent's turn.

3) Soccer: The ball reflects off all four sides of the pitch, except for the goal mouth. The goalkeeper defends this in the same way that the bats defend their court in the other games. The player has a second man on the field for soccer — the forward. This man will act like a bat when faced with a ball moving towards his own goal — the ball reflects towards his opponent's goal — but when the ball is moving in the right direction (towards his opponents side) the ball passes through him. However by careful positioning of the forward the ball can be made to deflect towards the goal.

4) Tennis: The game of TV Tennis is widely known and on Selecta-game the only unusual features are those listed in the specification.

SPECIFICATIONS — ETI 804

Output	**Picture: TV signal on channel 6 (can be set up on any other channel).** **Sound: Three audio tones indicate hit, bounce and score. Reproduced from a loudspeaker in Selecta-Game.**
Players' Controls	**Each player uses a single rotary control to position his bat/men on the screen. In the practice game one control operates; for tennis, soccer and squash two players each have a control. For the rifle games a special rifle is needed (not described in this article).**
Game Selection	**Basic Games:** **1) Practice — 2) Squash** **3) Soccer — 4) Tennis** **Other Games (these cannot be played without a special rifle):** **5) Rifle—1 — 6) Rifle—2**
Scoring	**On-screen scoring up to a maximum of 15 points.**
Other Features	**Two ball speeds** **Two bat sizes** **Two angles ± 20^{o}; or four angles ± 20^{o} & ± 40^{o}.** **Manual or automatic service**

USING YOUR SKILL

With the 'Angles' switch at '2' the ball moves across the screen at ± 20^{o} from the horizontal. When hitting the sides and walls of the court the laws of reflection are obeyed. When the ball hits the bat this isn't always the case: a ball hitting the top half of the bat will leave with an upward trajectory, and a ball hitting the bottom half of the bat will bounce downwards. This effect can be utilised by the skilful player — when the soccer forward is used to change the direction of the ball as it approaches the goal it usually beats the goalkeeper.

With the 'angles' switch at '4' the game becomes even more exciting. Now the bat has to be divided into quarters: starting from the top and working down the angles of the emerging ball are $+40^{o}$, $+20^{o}$, -20^{o}, -40^{o}. And if you can cope with that try switching to small bats and high speed ball! ●

Project 804

SELECTA-GAME

Many readers have asked us to design a gun project for the Selecta-Game. However this is not economically worthwhile if designed to our standards. Here we look at a commercially-available gun and give sufficient details for the experimenter to build up a similar unit.

SINCE PUBLICATION OF THE TV game project in November 1976 many thousands have been built by our readers. Many of these people have asked us to publish the rifle circuit for use with this unit. The trouble with designing a rifle or gun is that it involves mechanical work and optics. Also the quantity of light obtainable from the TV screen is very small and the differential between being on-target and off is very small.

We had therefore decided not to publish a rifle project but then Dick Smith gave us a plastic gun which included a pickup transistor and a lens.

What we have presented here is the gun and the circuit used in a commercial unit and it does work. Its limitations are that it will work only over a short range (about 1 metre) and the sensitivity control is extremely sensitive. Due to these limitations we decided not to present this as a complete project as we normally do but we are just printing the circuit to allow you to decide on your own means of construction.

If better optics are used longer range and less critical adjustment should result.

Modifications

The control pots on the Selecta-Game wear out quickly in continuous use unless wire-wound types are used. However, wire-wound pots of the correct value are not readily available, so we have designed a circuit which will allow 10 k pots (which are easily obtained) to be used. This involves modifying the game to add two transistors, two diodes and four resistors.

Some of the ICs do not like to operate on 6 V and as the batteries do not last long this has proven troublesome. Therefore we suggest you use a 9 V battery (or 6 x 1.5 V cells). This may change the internal adjustment slightly, necessitating re-alignment.

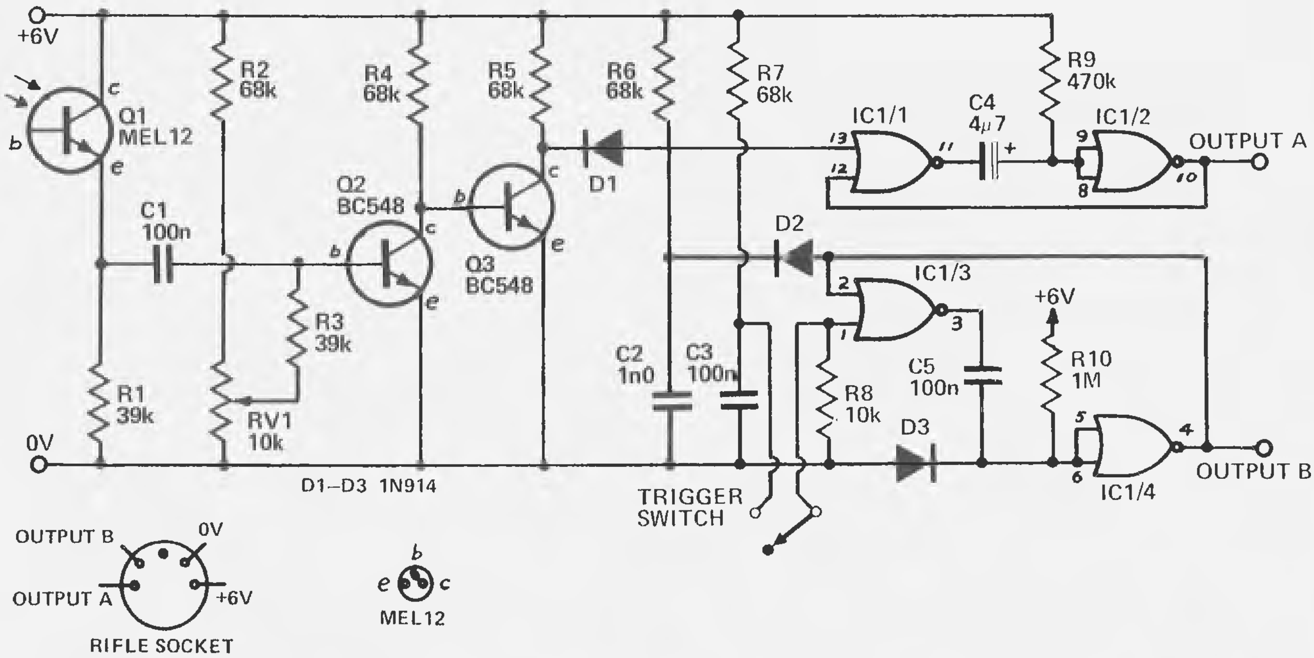


Fig 1. Circuit diagram of the gun.

This is the plastic gun assembly used in a commercial game. These guns (including lens and switch, but not the phototransistor) are available from Dick Smith Electronics for $6.50 each.

PARTS LIST
TV GUN

Resistors all ½ W 5%

R1	39 k
R2	68 k
R3	39 k
R4-R7	68 k
R8	10 k
R9	470 k
R10	1 M

RV1 Potentiometer 10 k lin rotary

Capacitors

C1	100 n polyester
C2	1n0 '
C3	100 n "
C4	4 μ7 16 V electro
C5	100 n polyester

Semiconductors

Q1	MEL 12 *
Q2,3	BC548
D1 - D3	1N914
IC1	4001 (CMOS)

* Q1 is part of gun.

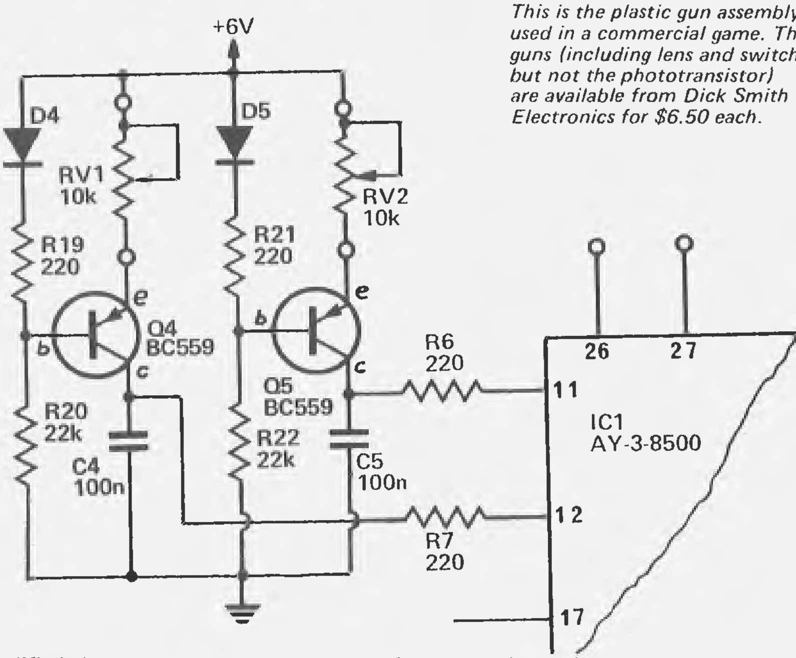
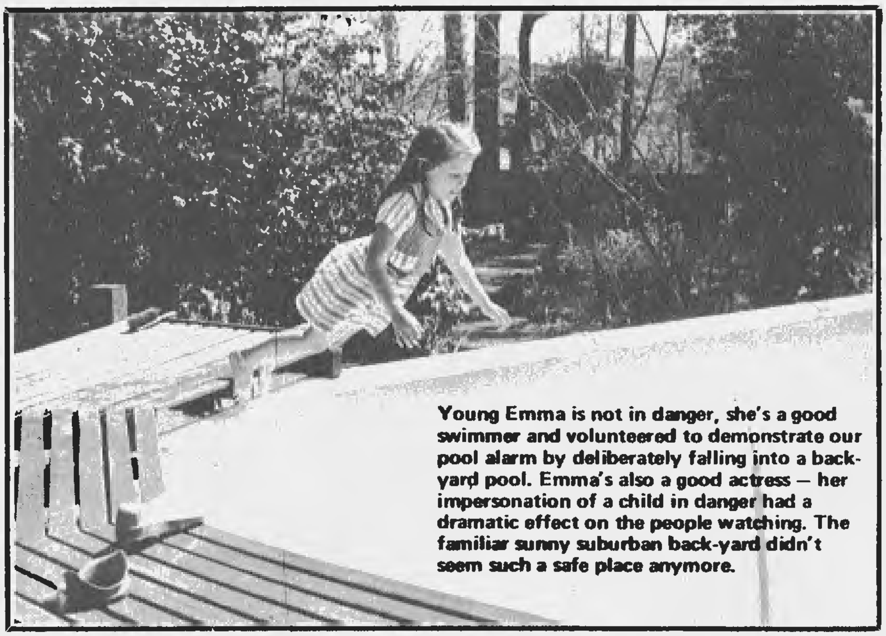


Fig 2. Modified circuit to allow wirewound potentiometers to be used.

SWIMMING POOL ALARM

Safeguard children with this easy-to-build alarm



Young Emma is not in danger, she's a good swimmer and volunteered to demonstrate our pool alarm by deliberately falling into a back-yard pool. Emma's also a good actress — her impersonation of a child in danger had a dramatic effect on the people watching. The familiar sunny suburban back-yard didn't seem such a safe place anymore.

EVERY YEAR fifteen to twenty children are drowned in home swimming pools. And that's in NSW alone.

In some States it is now compulsory to erect a high fence — with a lockable gate — around the pool. But even three and four year olds can and do climb fences, and gates are only too easily left unlocked. Even if fenced in, some form of reliable warning device is essential.

Some time ago Electronics Today ran a design contest inviting readers to submit their solution to this increasing problem.

Three main types of alarm were submitted.

1/ Floating devices that sense water ripples.
2/ Hydrophonic devices that detect the sound component of the splash.
3/ Light beams and sensors guarding the perimeter of the pool.

The most completely effective entry was a hydrophonic device that detected the sound of the splash. This unit had an inbuilt spectrum analyser to eliminate false alarms. Although ingenious and effective the device ultimately proved too complex to present as a constructional project.

A light beam and photocell barrier can also be very effective but it is difficult (in practice) to ensure the alignment of the system right around the pool. One entrant suggested that three parallel beams be used. The first two were spaced close together — the third was about one and a half metres from the ground. The outputs from the photocells were connected to a logic system set up so that no alarm would sound if all three beams were broken — or only one was broken. Thus birds and adults could pass through the beams at any time without causing alarm. A toddler however would break the lower *two* beams thus sounding the alarm.

The simplest and potentially most reliable systems used some form of differential float to sense water surface ripples. The basic principle of these devices is that only ripples *shorter* than the spacing between the floats will cause one float to move with respect to the other. Long wave ripples (such as those caused by wind blowing across the pool) will move the assembly as a whole.

One design of this type was submitted by Mr. G. Goodwin. This system has been further developed and extensively tested since the contest and is presented here in a form suitable for building by anyone who can use simple tools.

The sensing part of the alarm consists of an upright central tube which is supported in the water by three small floats. The central pillar carries a further small float which is free to move up and down the pillar.

This moving float has a pair of small magnets sealed within it, and a magnetically operated reed switch is housed within the central pillar — near the top.

The whole assembly floats in the water, with the central float normally resting some short distance below the point at which the reed switch is actuated.

In the event of a short sharp wave, such as that caused by a toddler or animal falling or slipping into the pool, the central float will be caused to momentarily rise with the wave thus actuating the reed switch.

Waves of longer pitch will move the assembly as a whole — there will be no differential movement.

Once the switch is triggered the alarm locks on and the warning mechanism will continue to sound even though the disturbing ripples have ceased. The alarm can only be turned off by pressing a reset button.

The unit's sensitivity is adjusted by moving the main float assembly up or down the central pillar. It is quite simple to set the unit so that it will respond only to the kind of waves produced by a child falling into the pool — but to ignore wind produced ripples.

As mentioned above it is necessary to have some type of circuit associated with the sensor to ensure that the unit, once triggered, will continue to sound an alarm even though the initial ripples die away.

The simplest way to do this is to use a relay with two pairs of contacts. One pair is used to connect power to the alarm bell — the second pair is used to cause the relay to 'self-latch'. This method is very reliable and has the advantage that almost any type of alarm bell can be used.

Figure 2 shows how the relay is connected to the float assembly. Twin bellwire or plastic coated lighting flex will be adequate for the wiring between the two parts of the unit. House the relay assembly and battery indoors so that it is dry and accessible.

We have not included an on/off switch in the circuit — it's too easy to forget to turn the unit back on. It's less convenient, but safer, to lift the sensor unit from the pool and to place it somewhere totally obvious when the pool is in use.

Connections may differ from relay to relay but if in doubt anyone with basic

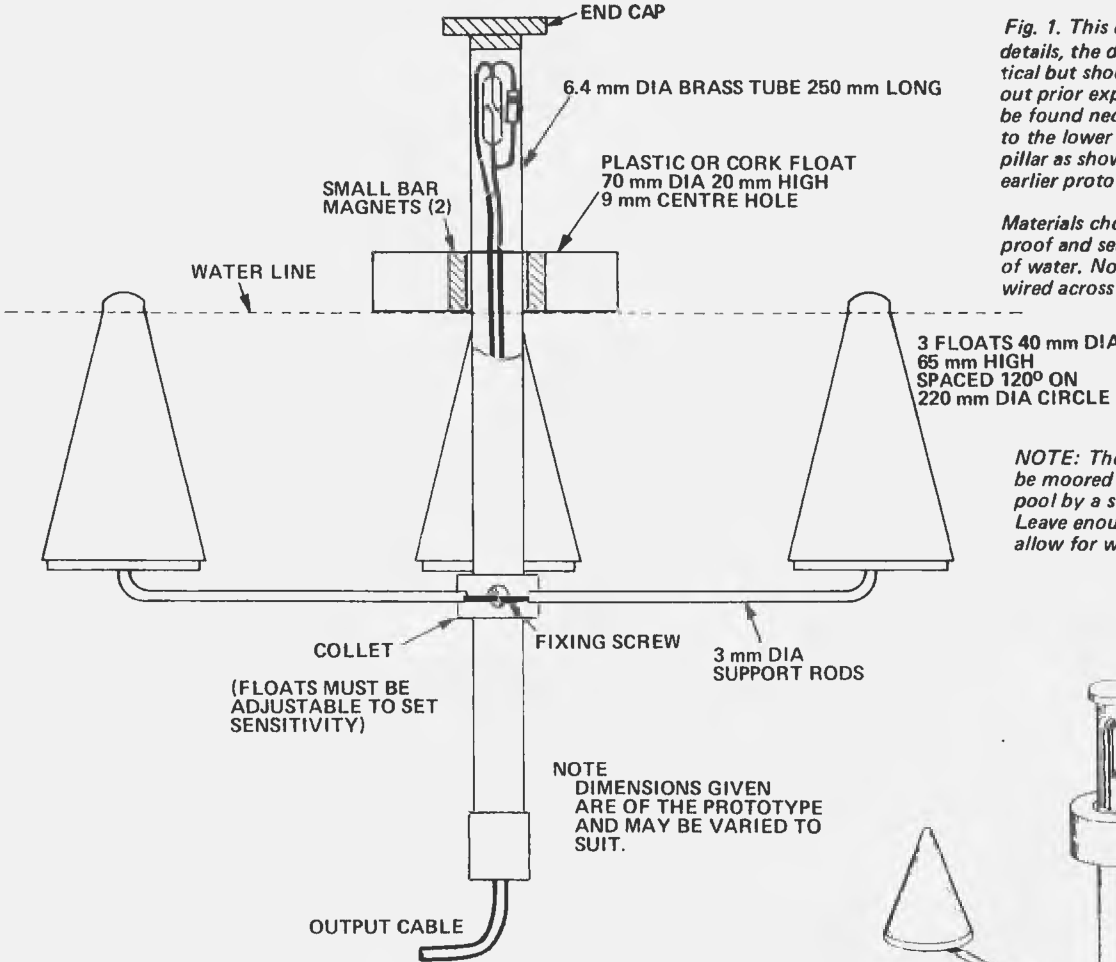
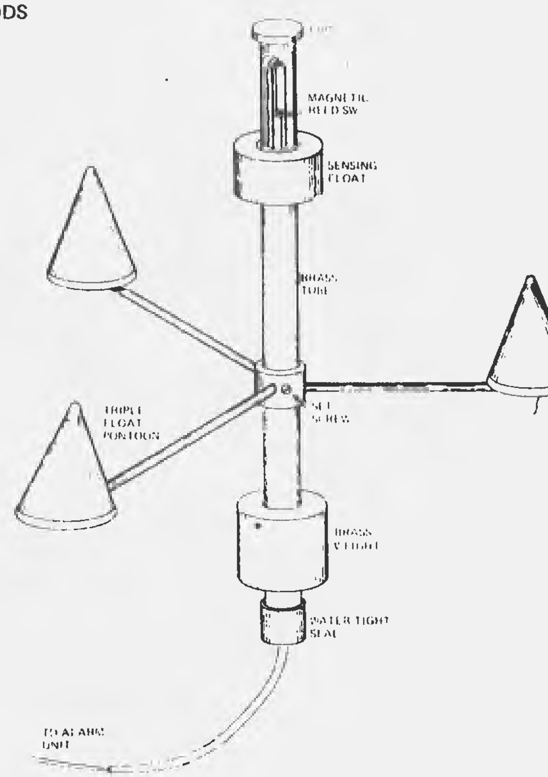
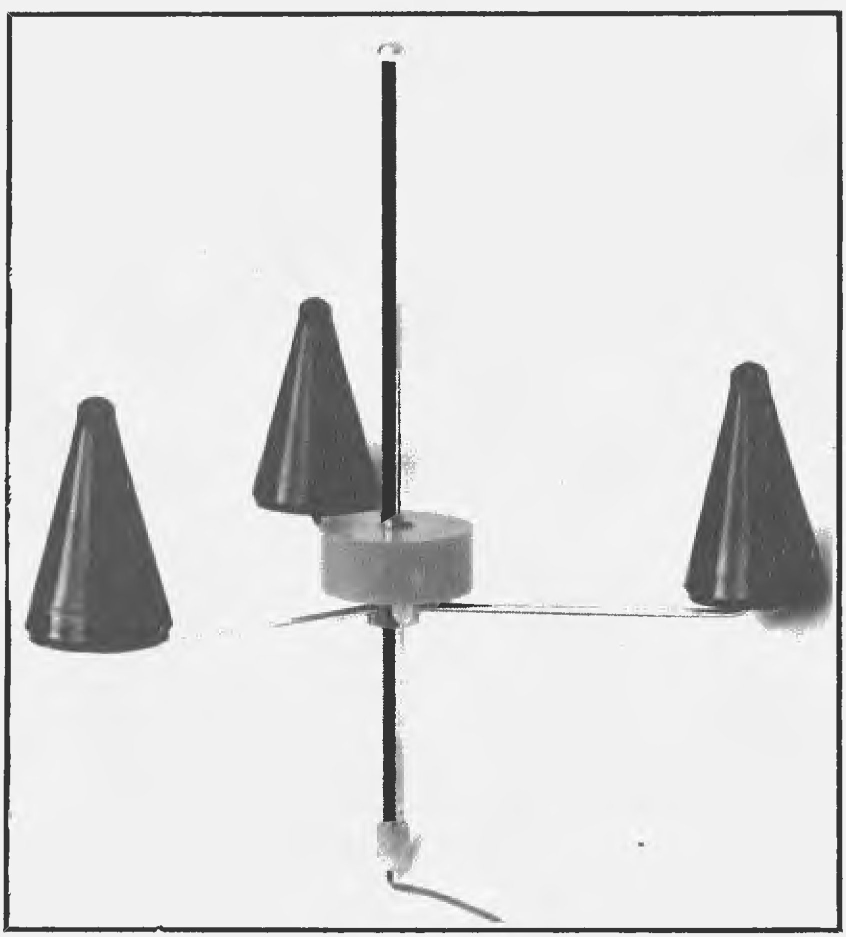


Fig. 1. This drawing shows the basic details, the dimensions are not critical but should not be varied without prior experimentation. It may be found necessary to add a weight to the lower part of the central pillar as shown in our sketch of an earlier prototype (right).

Materials chosen must be corrosion-proof and sealed against the ingress of water. Note how the diode is wired across the reed switch.

NOTE: The complete unit must be moored near the centre of the pool by a suitable cord and weight. Leave enough slack in the cord to allow for water level variations.

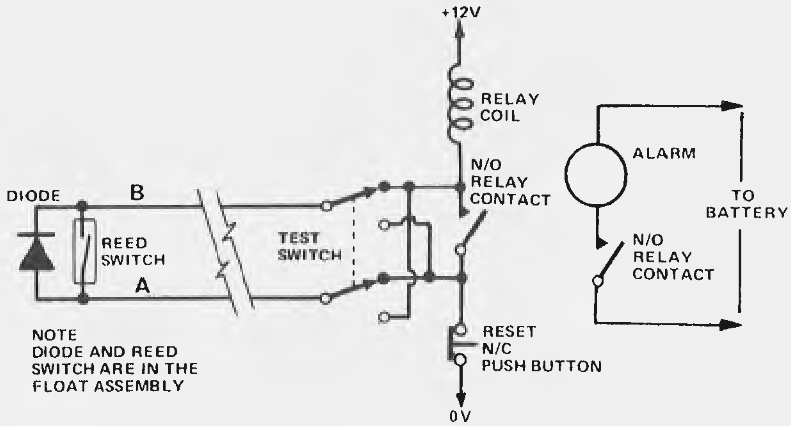




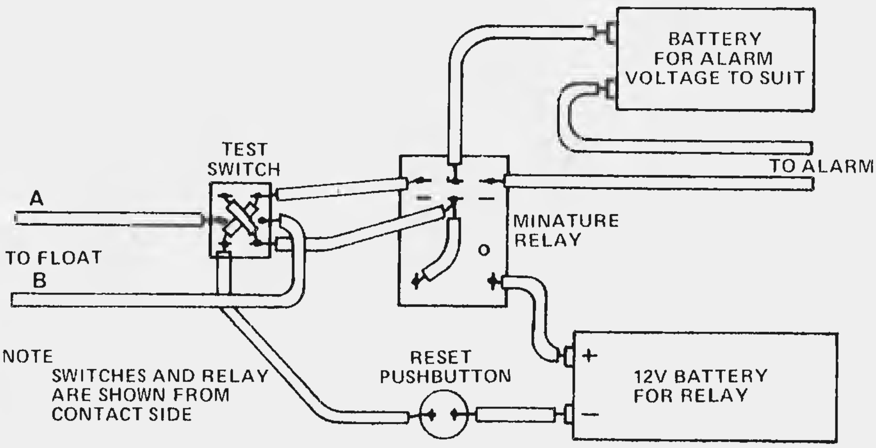
PARTS LIST

One double pole change over switch-any type
One push-to-break pushbutton switch
One double pole single throw (or change over) relay suitable for 12 volt operation.
One diode – any signal diode
One ORD 234B reed switch (or similar)
Two FM 454 magnets
Materials for float as obtainable

SWIMMING POOL ALARM



Figures 2 and 3 show how the unit is wired. The relay connections shown are for a conventional double pole unit. If the test facility is not required just leave out the diode and the test switch – simply connect the leads from the float assembly directly across the appropriate normally-open relay contacts.



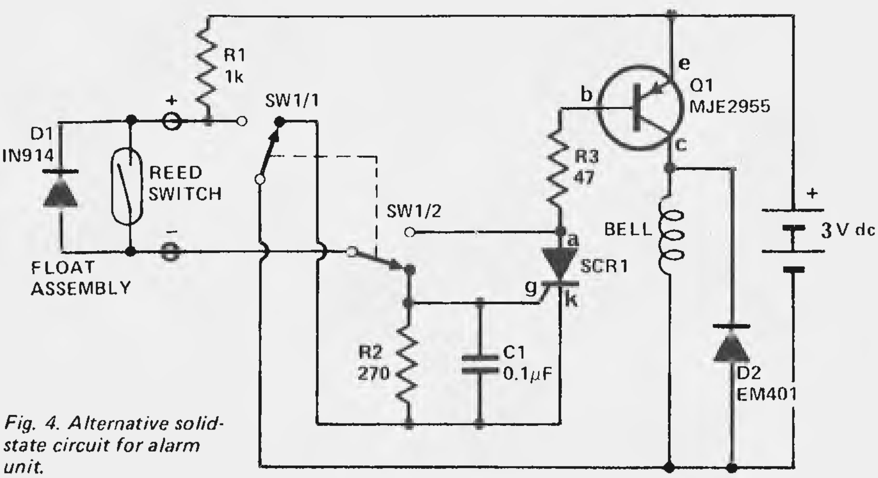


Fig. 4. Alternative solid-state circuit for alarm unit.

electrical knowledge will be able to tell you which connection is which.

The float assembly should conform generally to the drawing shown in Fig. 1. The central pillar may be made of brass or plastic tubing – but not steel. The floats were originally moulded specifically for the project out of polythene. They can however just as readily be made from light wood (well varnished to prevent water absorption) or cork. Plastic bottles or jars can also be adapted.

The reed switch and diode must be very securely fixed within the central pillar – which must then be securely sealed to prevent the ingress of water. An excellent way to do this is to fill the entire column with windscreen sealant or similar plastic goo.

The completed float assembly should be moored in the centre of the pool by a cable and weight resting in the bottom of the pool. Allow sufficient slack in the cable to allow for variations in the depth of water in the pool.

Figure 3 shows an alternative electronic switching and latching circuit. This is a form of construction suggested by Mr. Goodwin. It has been chosen so that the whole unit will fit into an existing Friedland door bell – which is powered by an inbuilt three volt battery.

This form of construction is certainly neat but in our opinion a simple double pole relay does the job equally well and with greater potential reliability. A 12 volt bell may also be used with the simple relay system and this will be heard over far greater distances than a simple door bell – no matter how adequate the latter may be for its originally intended purpose.

A diode is wired across the reed switch in both circuits. The purpose of this diode is to enable the entire wiring circuit to be checked for integrity by pressing a 'test' button. This facility does not of course check the reed switch itself nor the actual floating assembly. In our opinion the whole unit should be checked daily by throwing a suitable mass into the pool. (A water filled football or one gallon can simulate the mass of a small child very adequately). ●

NOTE

This unit has been extensively tested and has proved to be both effective and reliable.

However like any mechanical or electrical device, failures can occur. It is therefore imperative to follow normal swimming pool safety precautions even though this alarm is in use.

Project 066

TEMPERATURE ALARM

This simple project uses a 555 and a few other components to sound an alarm when a preset temperature is sensed.

THIS IS A SIMPLE BUT VERY versatile temperature monitor which can be used in three different ways:

1. To warn if temperature exceeds a preset level.
2. To warn if temperature falls below a preset level.
3. To control temperature.

The unit may be used to monitor temperature in fish tanks, laboratory ovens and/or water baths, incubators, cooking vessels, etc.

The temperature at which an alarm is given is adjustable over a range predetermined by the combined values of the components RV1 and R1. RV1 is a potentiometer which is used to adjust the final 'set point' (the temperature at which the alarm is given).

Actual temperature sensing is done by a device called a 'thermistor'. This is basically a resistor in which the resistance value varies with changes in temperature. Thermistors are obtainable in innumerable shapes, sizes and temperature ranges.

The unit may be built so that a small loudspeaker provides an audible warning when the set limit is reached (Fig. 1) or alternatively a relay may be connected which in turn switches the controlled heating load's electrical element on and off – thus producing a simple temperature control system (Fig. 2).

Either unit may be constructed so that the warning (or relay action) takes place as temperature *exceeds* the set limit – or so that the warning (or relay action) takes place as temperature falls *below* the preset level.

All that is required to convert either unit from one mode of operation to the other is simply to change over the position in the circuit of the thermistor and the combination RV1 and R1.

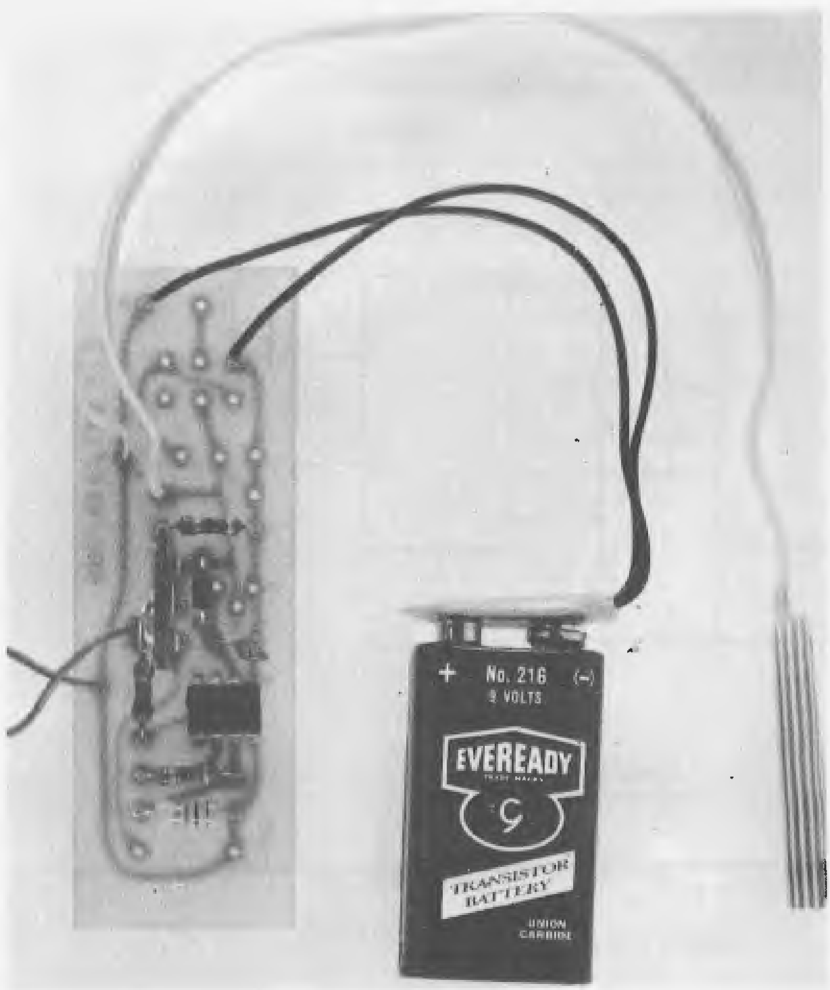


Figure 1 shows the unit with loudspeaker set up to warn if the temperature exceeds the limit preset by RV1. Figure 2 shows the circuit converted for relay output operation, set up so that the relay coil is energized when the temperature falls below the preset limit. Thus if an associated heating element is connected via the relay contacts, the element will be energized when temperature drops and will be switched off when the preset temperature is reached.

Project 066

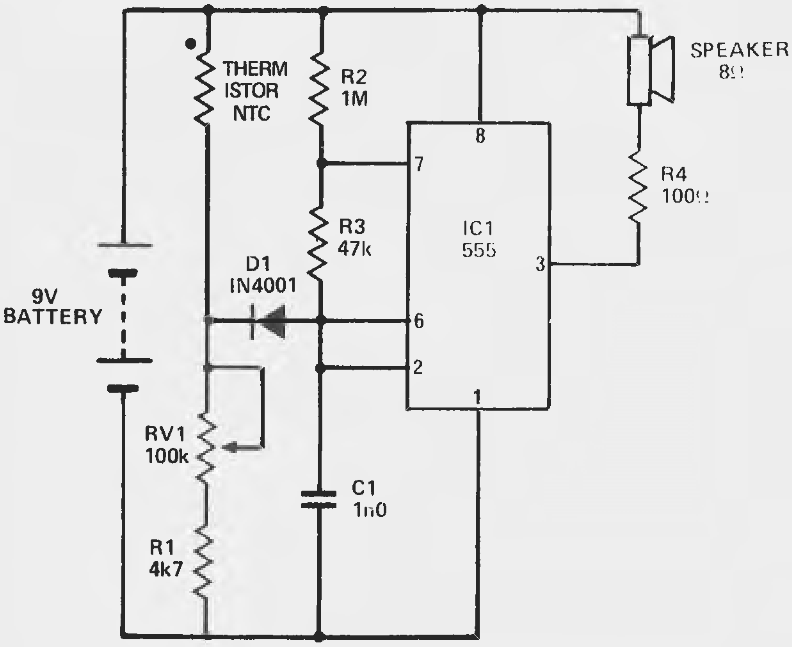


Fig.1. Basic circuit provides audible warning if temperature exceeds set point adjusted by RV1. See text if opposite operation is required.

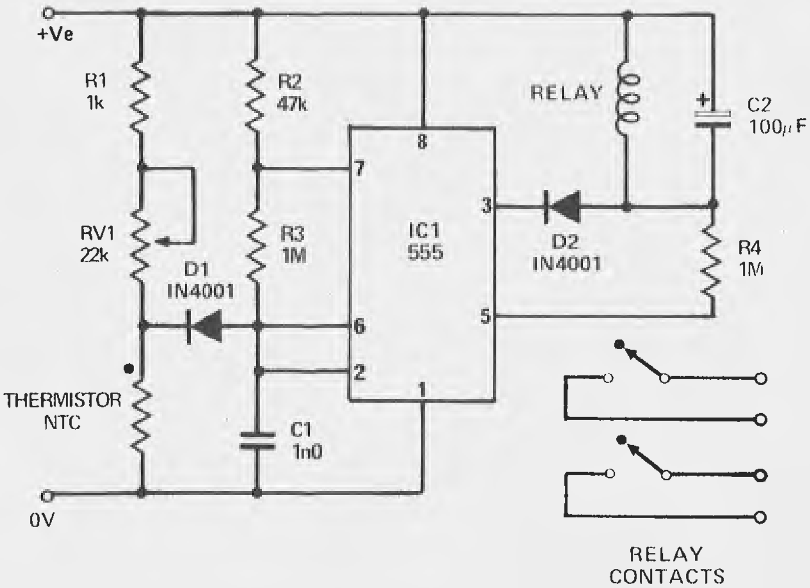


Fig.2. Unit set up for relay operation. Relay coil is energized when temperature falls below set point.

PARTS LIST ETI 066

Over-alarm

R1	Resistor	4k7	½ W	5%
R2	"	1 M	"	"
R3	"	47 k	"	"
R4	"	100 M	"	"
RV1	Potentiometer	100 k	Trim type	

Thermistor 47 k (25 °C) Philips
type 2322 642 11473

C1	Capacitor	1n0	polyester
D1	Diode	1N4001	
IC1	555 Timer		

Speaker 8 Ω

PC board ETI 066
or Veroboard 3.3 x 1.1"
9 V battery

HOW IT WORKS ETI 066

Temperature is sensed via a thermistor. This is a resistor which varies its resistance as temperature changes. The one chosen for this application is a NTC (negative temperature co-efficient) type in which resistance falls as temperature rises. The resistance at 25 °C is about 47 k falling to about 3 k at 100 °C. This thermistor forms a voltage divider with RV1 and R1.

The familiar 555 IC is the basis of the unit. The IC will oscillate if pins 2 and 6 are allowed to exceed approximately 2/3rds of the supply voltage, however the voltage divider along with diode D1 can prevent this and while it does so the alarm will be off.

As temperature increases thermistor resistance falls and the voltage begins to rise at the junction of D1, the thermistor and R1. When the voltage reaches 2/3 V_S – 0.6 V the 555 begins to oscillate and causes the loudspeaker to sound (at about 1.2 kHz). If an 8 ohm speaker is available then R4 must be included. However if an 80 ohm speaker is available then R4 may be left out – the sound will then be much louder.

Figure 1 shows the unit set up to sound an alarm as temperature exceeds the set point. If an alarm is required as temperature falls below the set point then the position of the thermistor, and the combination of RV1 and R1 should be reversed – i.e., so that the thermistor is connected to the negative supply rail.

The circuit may be arranged so that a relay is actuated rather than an alarm. Figure 2 shows how this is done. Here diode D2 and capacitor C2 rectify the output of the 555 IC. Resistor R4 is added to ensure that there is some overlap between pull-in and drop-out set points. The lower the value of R4 the greater the difference there will be between these two points (this effect is known technically as 'hysterisis').

Figure 2 is set up so that the relay coil is energized when temperature falls below the set point. As with Figure 1 opposite action may be obtained by reversing the position of the thermistor and the combination of RV1 and R1.

Building the unit

Constructional method is not at all critical – we show the unit made up on Veroboard and also on a printed circuit board for those who wish to use this simpler and more elegant method.

The thermistor should be mounted in the end of a short length of thin-walled glass tube and sealed with epoxy resin. Thermistors can actually be bought commercially already mounted in this way – but they're expensive.

There are two reasons for sealing the thermistor in the manner described above. Firstly, if the thermistor is not sealed electrolytic action will very quickly dissolve the thermistor leads – our's lasted just one day! Secondly, if the thermistor is used to monitor the temperature of an open element such as a heating jug there is a very real danger of the thermistor or its leads contacting mains voltage. If the thermistor is used solely for monitoring air temperatures then no sealing is of course required.

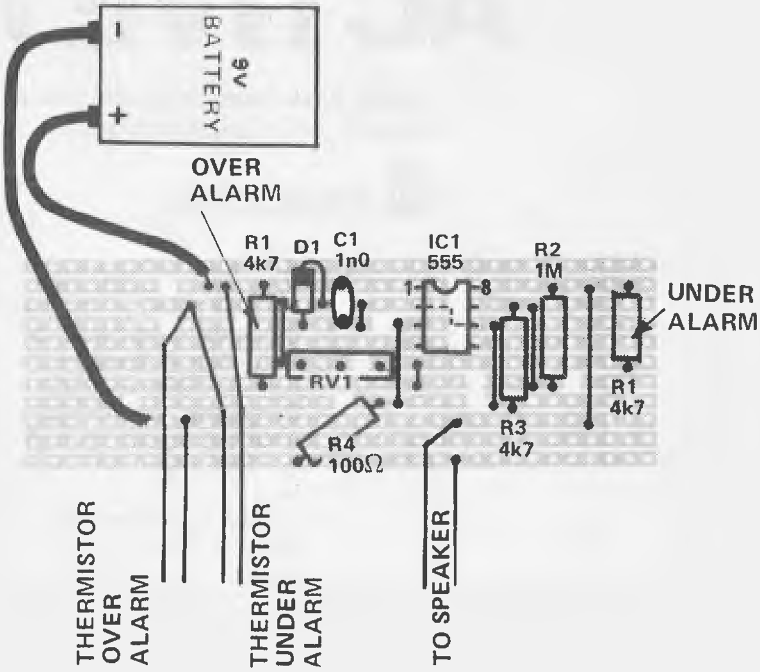
As outlined above, the combined values of R1 and RV1 determine the temperature at which the unit triggers. Table 1 shows roughly what the combined resistance should be for various triggering temperatures. Thus for the unit to operate at high temperatures the 100 k potentiometer and the 4k7 resistor specified will enable the set point to be adjusted from about 20 °C to about 82 °C.

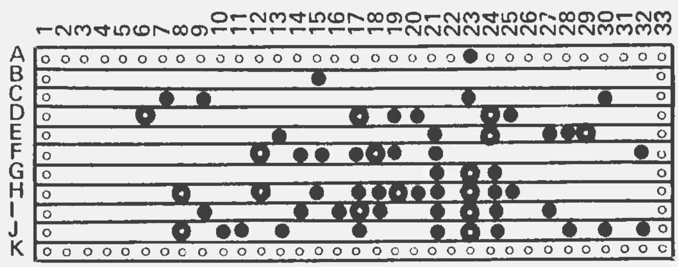
If finer control is required then the 100 k potentiometer could be replaced by a 25 k potentiometer and R1 increased from 4k7 to 75 k.

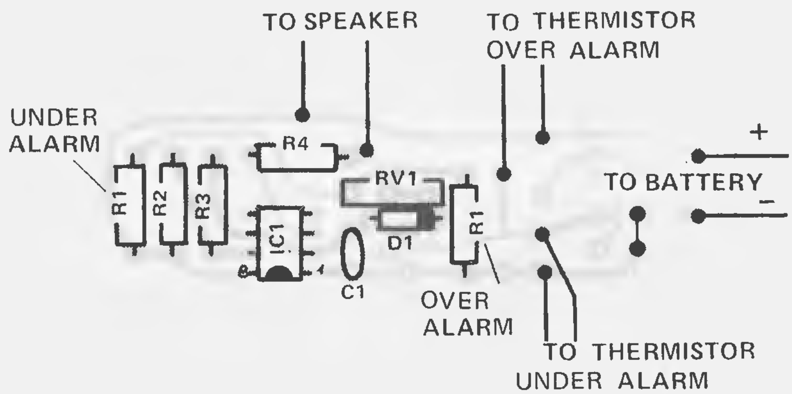
TABLE 1 ETI 066

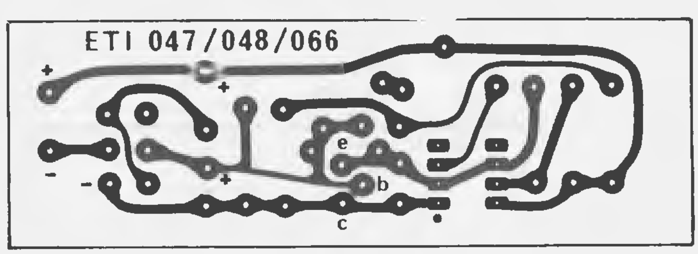
APPROXIMATE VALVES OF R1 + RV1 FOR DIFFERENT TEMPERATURES

TEMP. °C	OVER ALARM	UNDER ALARM AND RELAY OUTPUT
25	75 k	22 k
35	50 k	15 k
45	30 k	10 k
55	18 k	7k5
65	10 k	5k2
75	6k5	3k8
85	4 k	2k7
95	2k5	2 k









ACTIVE ANTENNA

Simple broadband antenna covers 0.5 to 30 MHz — or can be used to boost single stations in the broadcast band.

eti PROJECT 708

SHORT wave listeners often have difficulty in installing a suitably adequate antenna — especially if living in a flat or home unit. Parents and neighbours may quite justifiably complain about large and unsightly structures. In addition there are difficulties in building an antenna which adequately covers the whole range of 0.5 to 30 MHz and there is also the problem of antenna portability if required.

DESIGN FEATURES

An efficient system consists of the antenna itself together with a transmission line to carry the signal to the receiver. The antenna and transmission line must be matched to each other if the maximum amount of signal incident on the antenna is to be transmitted to the receiver. However since the size of an antenna is related to frequency, one particular sized antenna will only be suitable for a limited bandwidth. Fortunately very efficient antennas are not always needed on the HF band due to the excellent sensitivity of modern day receivers.

A rod antenna has an impedance of less than 50 ohms at its tuned frequency and can therefore easily be matched into a 75 ohm coaxial cable. However if a quarter-wave rod antenna is used at frequencies lower than its natural resonance its impedance increases so that it cannot easily be directly matched into a 75 ohm cable.

Our solution to the problem of obtaining wide band operation with a simple rod antenna is to feed it into an active impedance converter before the transmission line.

An active impedance converter must have a very high input impedance and low input capacitance. At low frequencies the effective input impedance is the value of the biasing resistor, whilst at high frequencies (above 1 MHz) the effective impedance is that of the input capacitance. The converter must have high linearity but no voltage gain. If voltage gain were incorporated the converter would have to provide a high power output to avoid the possibility of inter-modulation occurring.

The number of transistors used have been kept to an absolute minimum as each transistor adds its own noise contribution to the signal coming from the antenna. Two transistors are used and these are both low-noise RF types.

One particular application for the antenna was to boost the level of the Sydney station 2JJ which is very low in level and cannot be received by an average car radio when driving around the city. When using the converter in a straight broad-band mode the reception from 2JJ was greatly improved but other strong stations overloaded the receiver producing some rather unpleasant distortion. For this reason the alternative circuit was developed to allow one particular station to be handled at maximum efficiency whilst with other stations away from resonance the converter impedance is lowered, thus reducing the output from stronger stations.

It must be remembered that if the signal level from a station is below the ambient-noise level it is impossible to improve the signal-to-noise ratio with any type of active antenna. For the short wave listener an occasional burst of noise is not so objectionable and the active antenna will give good results over the entire 0.5 to 30 MHz band. It must be remembered that when operating in a car the signal level from shortwave signals will be improved but the apparent noise level may also increase if it is raised above the masking of the ambient noise level in the car.

CONSTRUCTION

The use of a printed-circuit will greatly simplify construction and the pattern provided will suit the car or broad-band version by simply adding some components or deleting others as required for the particular version.

Broad-band SWL version

After the printed-circuit board is assembled in accordance with the respective overlay it is fitted into a small metal box (a diecast box is best as it may be more easily sealed against moisture) upon which a commercial car whip antenna is mounted as shown in the photo. Lead was placed in the bottom of the box so that the unit will not tip over easily and rubber feet were fitted to raise it above surface water when used outside. The coax is fed in through a hole in the bottom of one side and a water seal is maintained by fitting the cable through a rubber grommet. Once the unit is checked out it is a good idea to spray the inside of the unit with clear lacquer to seal against moisture.

For those who do not wish to purchase a commercial antenna a length of ordinary hook-up wire taped to a light wooden support or even taped to the wall is adequate. Make sure however that the wall is non-metallic and that the antenna is not close to any electrical wiring or other metallic structures.

Car or broadcast version

From Table 1 determine the number

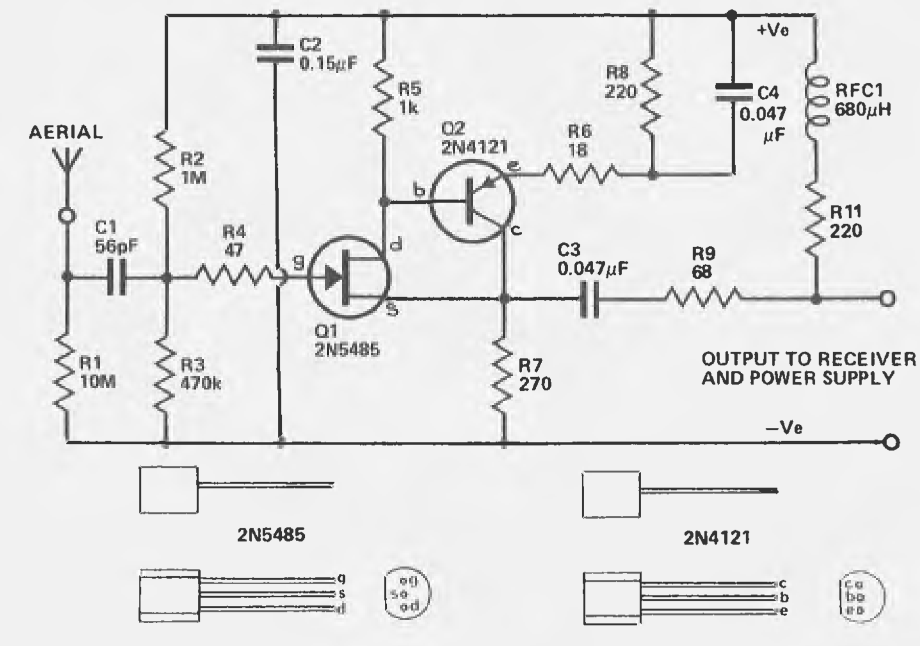


Fig. 1. Circuit diagram of the SWL version (0.5 to 30 MHz).

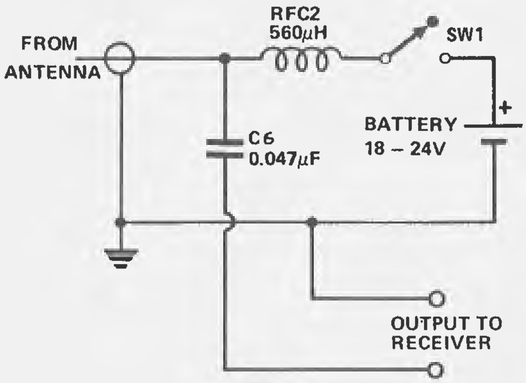


Fig. 2. Circuit for combining supply volts and antenna signal onto the coaxial feeder cable. Used with SWL version where long feeder cable is required.

PARTS LIST — ETI 708

R6	Resistor	18 Ω	¼ W	5%
R4	"	47 Ω	"	"
R9	"	58 Ω	"	"
R8,11	"	220 Ω	"	"
R7	"	270 Ω	"	"
R5	"	1 k	"	"
R3	"	470 k	"	"
R2	"	1 M	"	"
R1	"	10 M	"	"
R10	"	See text		
C1	Capacitor	56 pF	Ceramic	
C5	"	5-70 pF	Philips 2222 808 01001	
C3,4,6	"	0.047 µF	Ceramic	
C2	"	0.15 µF	"	
Q1	Transistor	2N5485 (FET) or similar		
Q2	"	2N4121 or similar		
RFC1	Radio frequency choke	680 µH		
RFC2	" " "	560 µH		
L1	See table 1			
SW1	Single pole single throw toggle switch.			
PC Board ETI 708				
coax cable				

HOW IT WORKS – ETI 708

In effect the active antenna consists of a rod antenna followed by a buffer amplifier which has a very high input impedance (to match the antenna) and an output impedance of 75 ohms to match the lead-in cable.

Signals picked up by the antenna are coupled to the amplifier via C1 the value of which has been kept small to attenuate any 50 Hz pickup on the antenna. Resistors R2 and R3 set the bias point for Q1 such that a four-volt drop is obtained across R7. The voltage gain is maintained at unity and the linearity improved by applying feedback from the collector of Q2 to the source of Q1. The function of Q2 is to provide a very low output impedance. Resistor R4 is used to suppress any parasitic oscillation which may occur to the high gain which both Q1 and Q2 have up to UHF frequencies. Resistor R9 increases the output impedance of the amplifier to match the 75 ohms of the coaxial cable.

In the broad-band version the supply current is fed to the unit via the coaxial cable – the shield being at earth. RFC1 and R11 appear as a very high impedance to the RF but as a low impedance of 250 ohm, to the dc. In effect it forms a low-pass filter in conjunction with C2. Capacitor C3 prevents the supply voltage from upsetting the bias conditions of the transistors. The signal is passed down the coax to the antenna circuit where C6 couples the signal to the receiver whilst blocking the dc, and RFC2 connects the dc supply to the coax whilst preventing the RF signals from entering the power supply.

In the broadcast version L1 and C5 form a parallel-resonant circuit that appears to one particular station in the broadcast band as a high impedance, and to the other stations as a much lower impedance. Thus the voltage developed at the input of the amplifier is a maximum at the frequency to which L1 and C5 are tuned, whilst the other stations are attenuated. Resistor R10, in series with the tuned circuit, sets a minimum value into which the short antenna works and so assures some response to the stations other than that tuned by L1 and C5. The value of R10 is best found by experiment as detailed in the text.

of turns necessary for L1 and wind it as detailed in Table 1. The coil L1 must be mounted close to the base of the antenna so that it can be connected to the antenna by no more than 75 mm of wire. The earth connection to the chassis must also be kept short and C5 should be mounted so that it is accessible for tuning.

A good place to mount the antenna is on the rear mudguard with the base protruding into the boot. The converter may then be mounted to an aluminium bracket which is secured to the car with the antenna base retaining bolt.

The converter should be fed with a 12 volts supply obtained from the accessory fuse in the fuse box.

On cars with generators that produce hash (interference) on the 12 volt supply an 820 microhenry choke, in series with the supply lead, and an 0.15 microfarad ceramic capacitor to ground (from where the two RFC chokes meet) should help.

SETTING UP

The transistor Q1 has quite a spread in parameters from one device to another and some circuit adjustment may be required for optimum performance. The voltage drop across R7 should be approximately one third of the supply voltage to the converter. That is, four volts for a supply of 12 volts. If necessary adjust this voltage by adjusting the value of R3. No other setting up is required on the SWL version.

In the car version temporarily place a link across R10, tune the receiver to the station which needs to be boosted and adjust C5 for maximum volume. This is best done when the car is parked in an area where poor reception is encountered. Resistor R10 is best selected by experimentation. A good starting value is 1000 ohms. Adjust R10 so that the stations to which L1 and C5 are *not* tuned are received free of noise. Too large a value of R10 will reduce the effectiveness of the tuned circuit. (see How it Works).

We found that an antenna length of two metres was suitable for the HF version and a one metre length was suitable for the broadcast band version.

TABLE 1

L1	Frequency	No of turns
	below 700 kHz	45
	700 to 950 kHz	34
	950 to 1200 kHz	26
	above 1200	20

CORE Philips potcore P18 series material 3B7 or 3H1, $\mu e = 220$ Part No 4322—022—24280 or 4322—022—24080
FORMER 4322—021—30270
CLIP 4307—021—20000
one each of core, former and clip required to assemble one complete coil

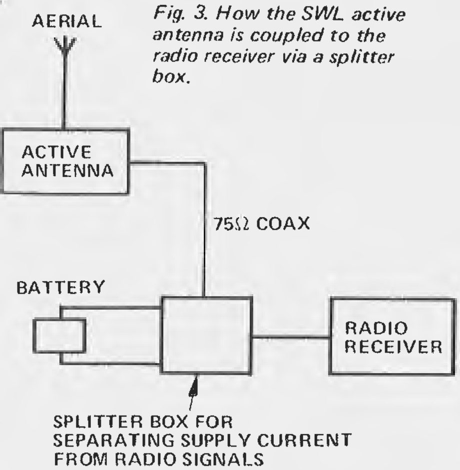


Fig. 3. How the SWL active antenna is coupled to the radio receiver via a splitter box.

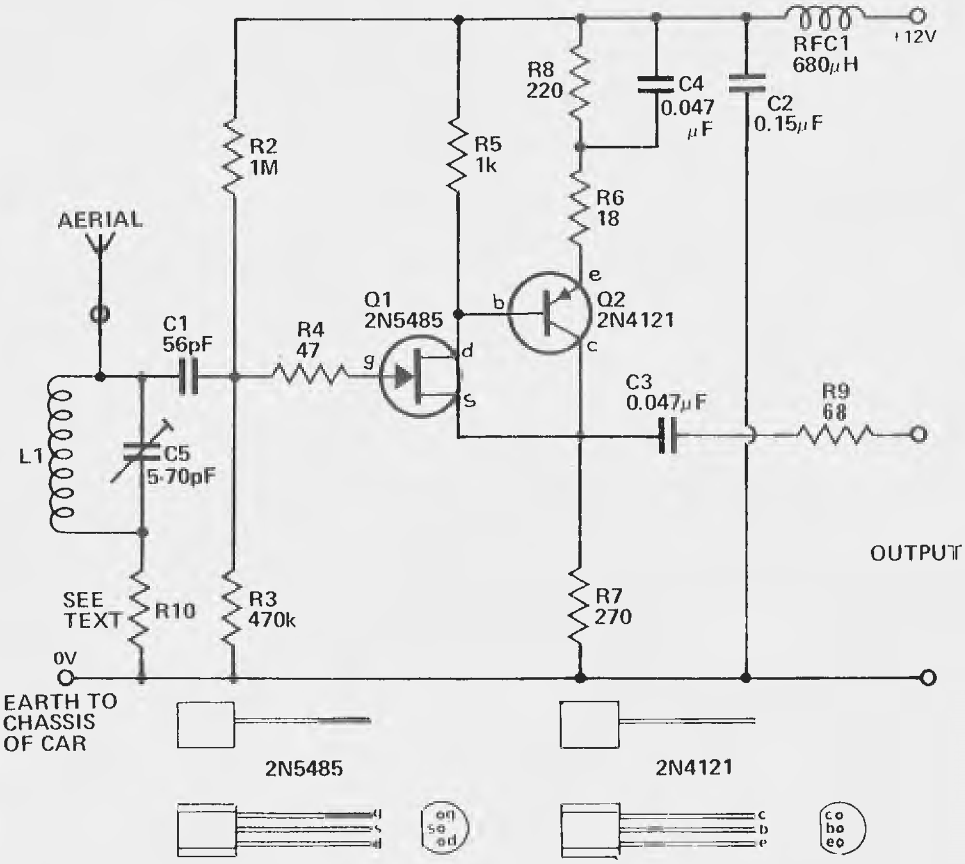


Fig. 4. Broadcast version has a tuned circuit, L1, C5 to attenuate stations other than the one tuned.

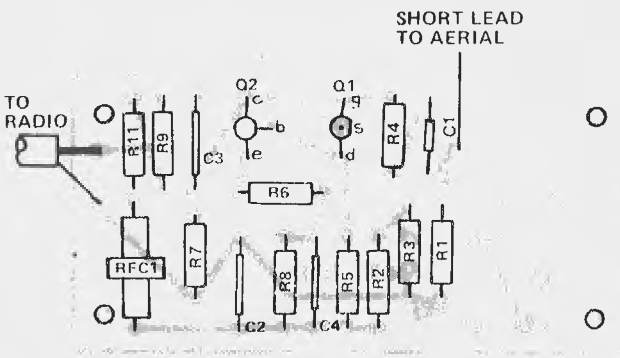


Fig. 5. Component overlay for the SWL version.

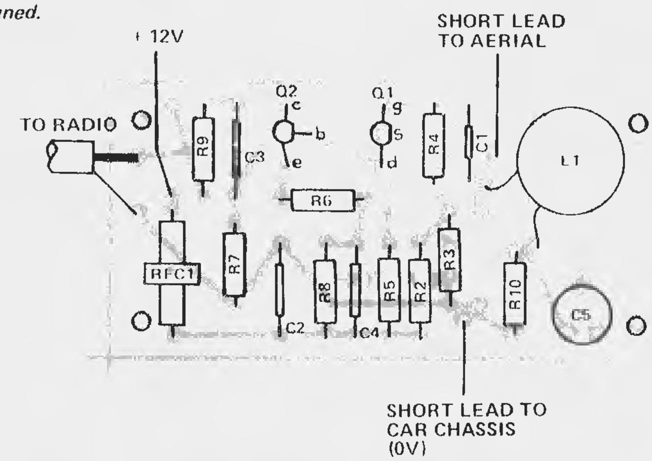


Fig. 6. The component overlay for the broadcast or car version. Note that the same printed-circuit board is used for both versions.

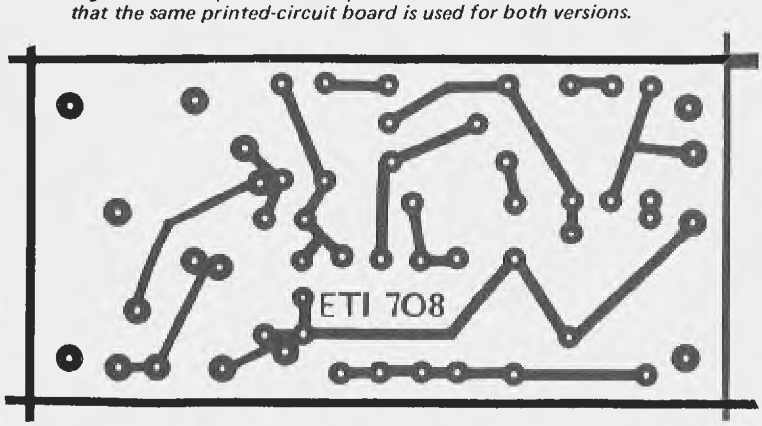
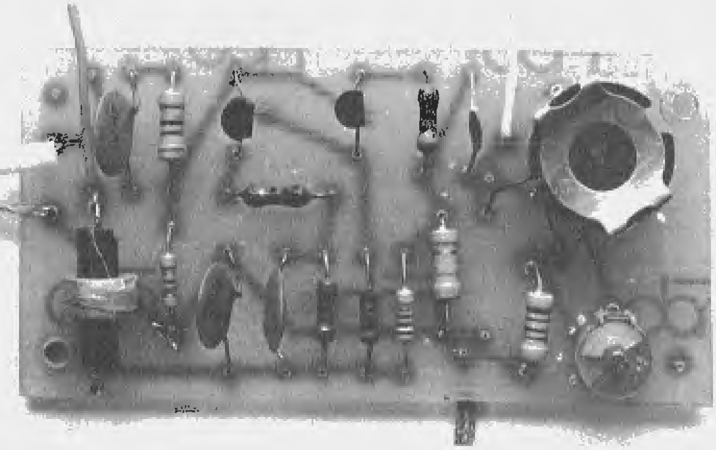


Fig. 7. Printed-circuit layout for both versions. Full size 92 x 46 mm.



◀ *How the finished board for the broadcast version appears.*

50 - 100 WATT AMPLIFIER MODULES

Project 480

(Continued from page 15)

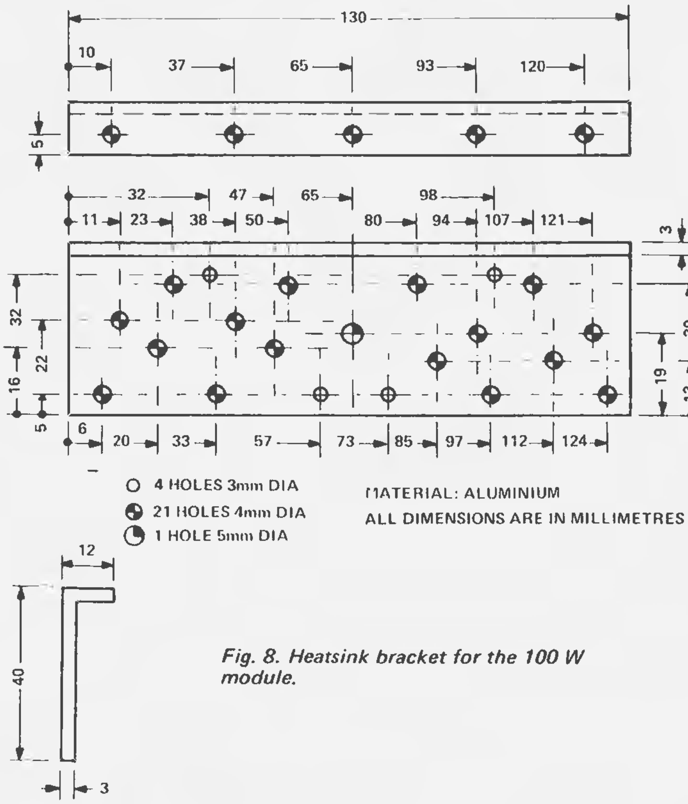


Fig. 8. Heatsink bracket for the 100 W module.

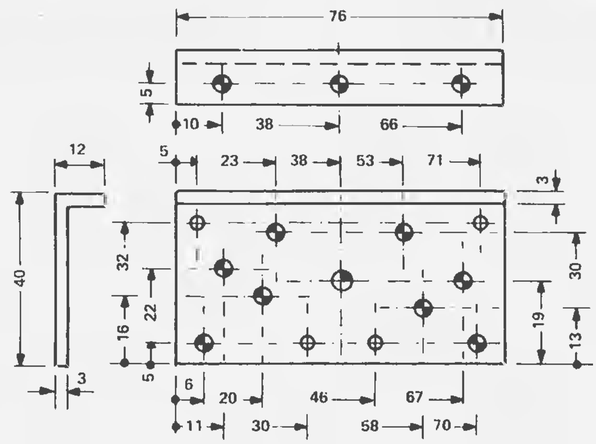


Fig. 9. Heatsink bracket for the 50 W module.

4 HOLES 3 mm DIA
11 HOLES 4 mm DIA
1 HOLE 5 mm DIA

MATERIAL: ALUMINIUM

NOTE
ALL DIMENSIONS
ARE IN MILLIMETRES

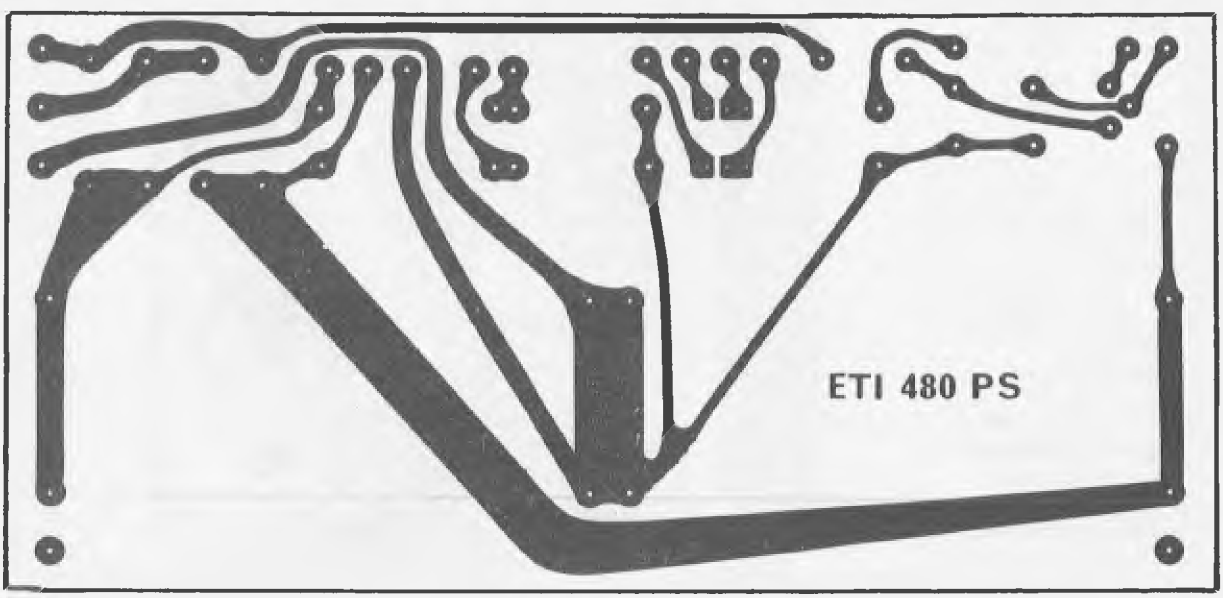


Fig. 7. Printed circuit layout of the power supply. Full size 160mm x 76mm.

Project 546

GSR MONITOR

Learn to reduce tension levels with ETI's galvanic skin response meter. Design by Barry Wilkinson — editorial by Jan Vernon.

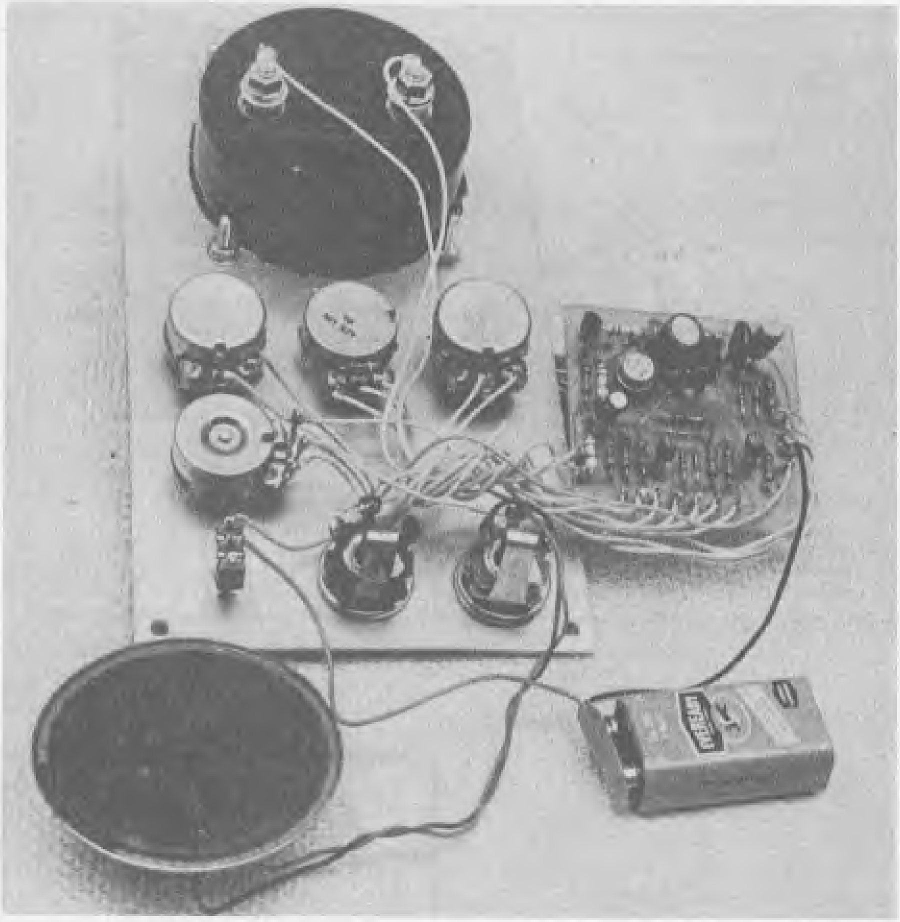
THE BEST WAY TO START EXPERimenting with biofeedback is to use a galvanic skin response monitor, a device which measures changes in skin resistance. In September 1976, we published an article which covered the background and theory of biofeedback and we discussed the various types of biofeedback instruments which are available. The GSR monitor is the most simple to use, the electrodes can be simply attached to the fingers with Velco straps and the technique of using the machine can be quickly learned.

Skin resistance changes with changes of emotional state. When tension increases, the skin resistance falls — when tension decreases there is an increase in skin resistance. (Some biofeedback instruction manuals speak in terms of conductivity rather than resistance and state measurements in mhos, and the meter we use gives a positive deflection for decreasing resistance.)

The connection between skin resistance and tension is not fully understood. Tension affects sweat glands and with the changes in the sweat glands there is a change in the membrane permeability of the skin and this change in permeability is the major cause of changes in electrical activity.

Almost a century ago, a scientist named M. Ch. Fere discovered the resistance of the skin to a small electric current changed in response to aroused emotions. This information has since been used in various ways; one obvious example is the polygraph, or lie detector, which responds to the tension generated when a person is lying.

It was not until 1961 that Dr. J. Kamiya, whilst conducting a series of



experiments with brain waves, found that with feedback his subjects developed the ability to produce 'Alpha waves' at will.

Dr. Kamiya's experiments created considerable interest and started investigations into whether other bodily functions could be brought under conscious control. Since that time it has been demonstrated that with feedback it is possible for people to control heart beat, blood pressure and temperature — all previously considered to be automatic bodily functions mostly beyond conscious control.

Of course it should be stated that various mystics and yogis have previously demonstrated this type of ability but the fascination of biofeedback is the speed and ease with which this type of control can be learned.

Biofeedback has exciting medical possibilities. GSR machines are being used by therapists for the treatment of many disorders related to tension. The average person will find a GSR machine mainly useful for relaxation training. With the GSR machine it is possible to recognise tension and learn how to decrease tension levels. This type of training is so effective that the machine quickly becomes unnecessary.

However not everyone suffers from tension. The biofeedback machine can be a fascinating toy to play with. Discovering that you can bring an internal bodily function under conscious control with the same ease that you can twitch your nose is most interesting. And of course you can then perfect this ability just as you perfect your ability at a game like tennis. For many people this is reason enough to build this machine.

What you do with it once you have built it

The ETI GSR monitor has an on/off switch, a sensitivity control and fine and coarse level controls. The machine also has a connection for headphones.

To start relaxation training, you'll need a comfortable chair, low lighting and no distractions. Taking any type of drug can interfere with your ability to relax. This applies to alcohol and cigarettes. Attach the electrodes to the fleshy part of the first two fingers on one hand — firm but not too tight (the non-dominant hand is recommended). Set the sensitivity control to minimum and the 'fine' level control to mid-range. Turn the volume control to minimum. Now you have to set the level with the 'coarse' level control (when the sensitivity is set low the 'fine' level control need not be used). Start with the 'coarse' control at full anticlockwise and turn it up until the meter needle starts to move. Carefully set the needle to mid-range. Now the instrument is set-up in its minimum sensitivity position.

Having mastered setting up with minimum sensitivity try to set the GSR monitor with the sensitivity set half-way. It will require delicate adjustment of the 'coarse' level control. Now the effect of the 'fine' level control can be seen. This control enables you to set the level on a high sensitivity setting.

Although the GSR machine measures minute changes in skin resistance, the level of skin resistance varies considerably from person to person so a wide range of settings is provided.

Now turn up the volume and observe that the meter reading is accompanied by a medium pitched tone. (A convention has developed to link high-pitched tone with tension increase and low pitched tone with a decrease in tension.) Now you relax and bring the tone down and the needle back to zero.

How? Basically you are supposed to find this out for yourself. After watching the needle for some time you will notice it move up or down. Something has happened to cause a change in your skin resistance. You would be barely aware of what had caused the change but aware enough to try to reproduce the effect. Eventually your awareness grows and so does your ability to control your tension. Many people find that relaxation of the stomach muscles makes the difference. It varies from person to person.

There are several relaxation techniques which work very well. One method is to tense all the muscles of the body as hard as possible, hold them tense for several seconds then very deliberately relax all muscles. There are several books and cassettes available which describe relaxation techniques. The techniques work. The biofeedback machine makes it possible to monitor progress.

As you relax, the needle on the meter and the audible tone will decrease. When the needle reaches zero, reset it again towards the fsd end of the scale and repeat the procedure.

Twenty minutes is the recommended time for a training session. After about one or two weeks of daily relaxation training, it should be possible to produce the same level of relaxation without using the machine and the machine can simply be used occasionally as a reference.

GSR MONITOR

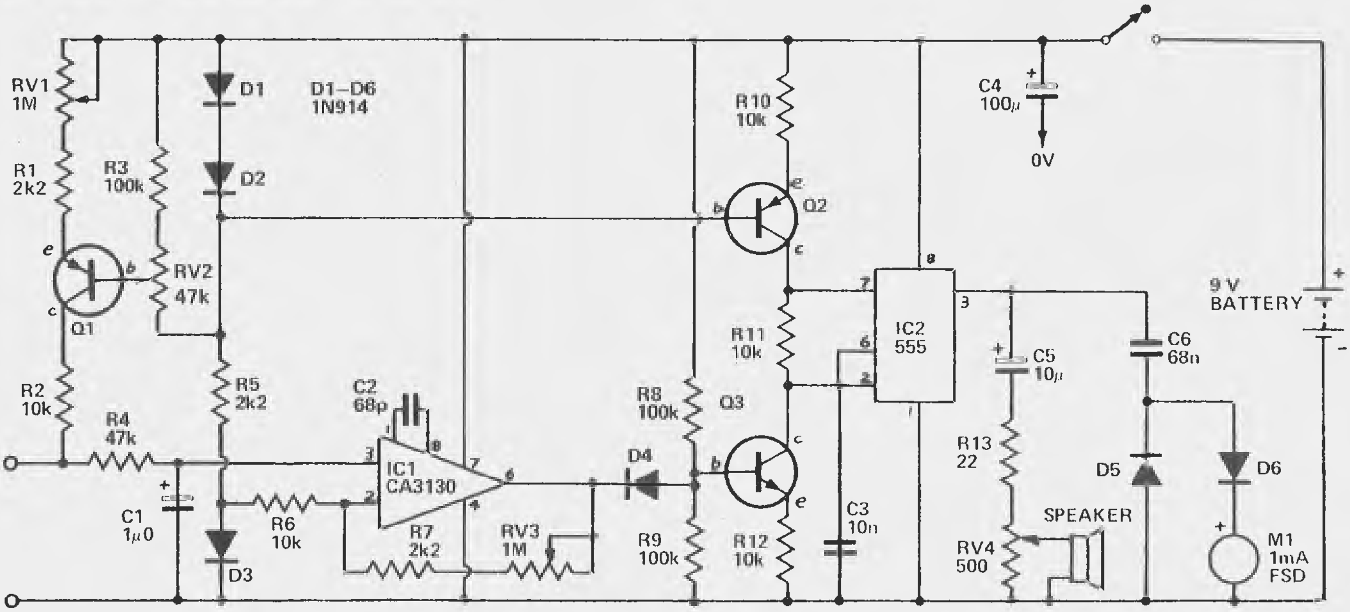
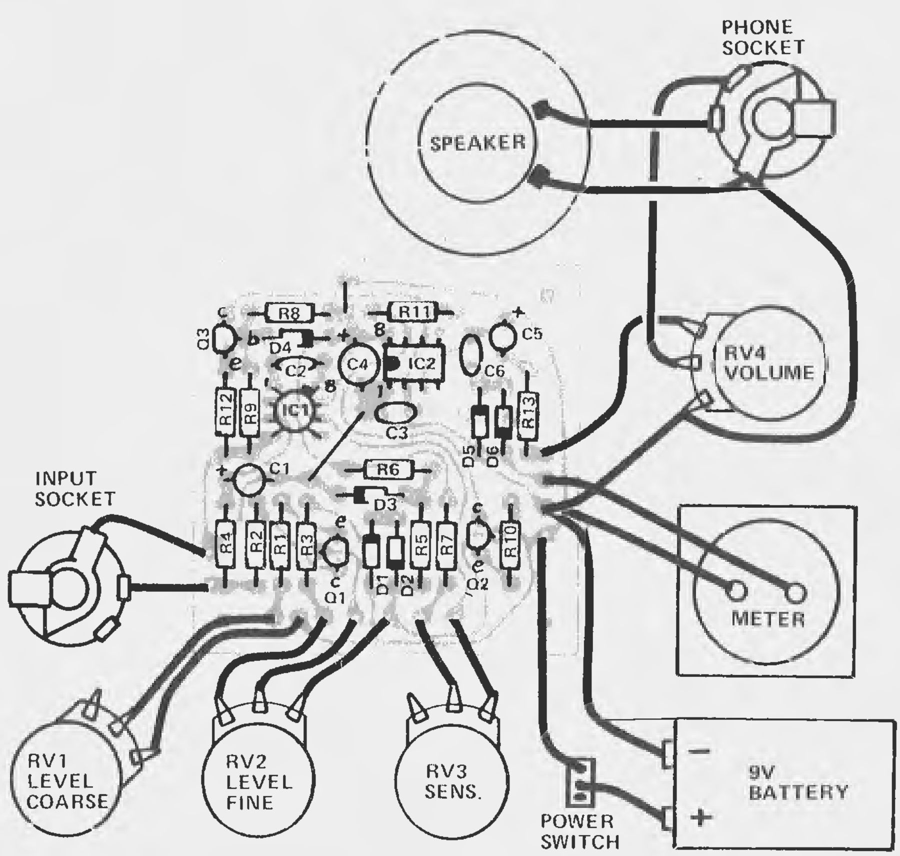


Fig. 1. Circuit diagram of the GSR monitor.

Fig. 2. Component overlay and interconnection diagram.



PARTS LIST ETI 546

Resistors all ½ W 5%

R1	2k2
R2	10 k
R3	100 k
R4	47 k
R5	2k2
R6	10 k
R7	2k2
R8,9	100 k
R10–R12	10 k
R13	22 ohms

Potentiometers

RV1	1 M log
RV2	47 k lin
RV3	1 M log
RV4	500 ohm lin

Capacitors

C1	1 μ 16 V electro
C2	68 p ceramic
C3	10 n polyester
C4	100 μ 16 V electro
C5	10 μ 16 V electro
C6	68 n polyester

Semiconductors

D1–D6	Diodes 1N914
Q1,2	Transistors BC559
Q3	Transistors BC549
IC1	Integrated Circuit CA3130
IC2	Integrated Circuit NE555

Miscellaneous

PC board ETI 546
Meter 1 mA FSD
Zippy Box 196 x 113 x 60
Two phone jacks
Four knobs
Small speaker
Six AA battery holder
Pickup probes

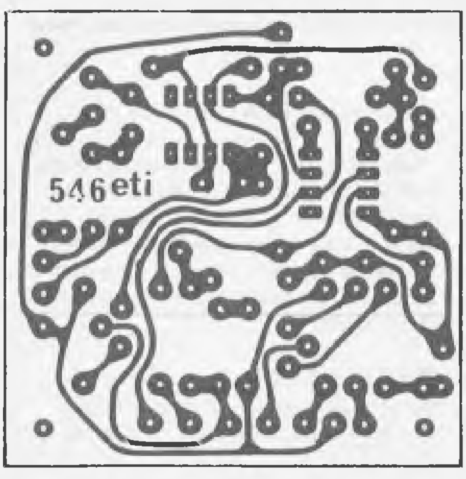
How It Works — ETI 546

This project measures the skin resistance and displays it on a meter. An audio tone gives an aural indication of the meter reading. The meter operates in reverse sense to a usual resistance meter: low resistance gives full scale (or high tone) and high resistance gives zero (or low tone). Skin resistance can vary over a large range but the variations studied in biofeedback experiments are small — so an offset is needed.

Transistor Q1 acts as a constant current source — the actual value can be varied over a large range by RV1 and over a limited range by RV2. These act as the coarse and fine level controls. This current is passed via R2 to the probes. The voltage developed across the probes is proportional to the skin resistance and is fed to the input of IC1. This amplifies the signal with reference to 0.6 V (drop across D3) and the gain is variable by RV3.

The second IC is an NE555 oscillator where Q2 provides a constant current (about 60 μA) to the capacitor C3. When the voltage on C3 reaches 6 V the IC detects this and shorts pin 7 to ground, discharging C3 via R11. This continues until the voltage reaches 3 V at which point the short on pin 7 is released allowing C3 to recharge. The output of the oscillator is connected to a speaker via the volume potentiometer RV4 and the meter via C6 and the diodes D5 — 6.

We vary the frequency of the oscillator and the meter reading by robbing some of the current supplied by Q2 into Q3. In this way the frequency can be lowered and actually stopped. Transistor Q2 is controlled by IC1 completing the connection between the probes and the output.



Construction

Construction is not critical although we recommend you use the pc board as it makes things easier. Before soldering the components made sure they are orientated correctly. External wiring can be done with the aid of the overlay-wiring diagram.

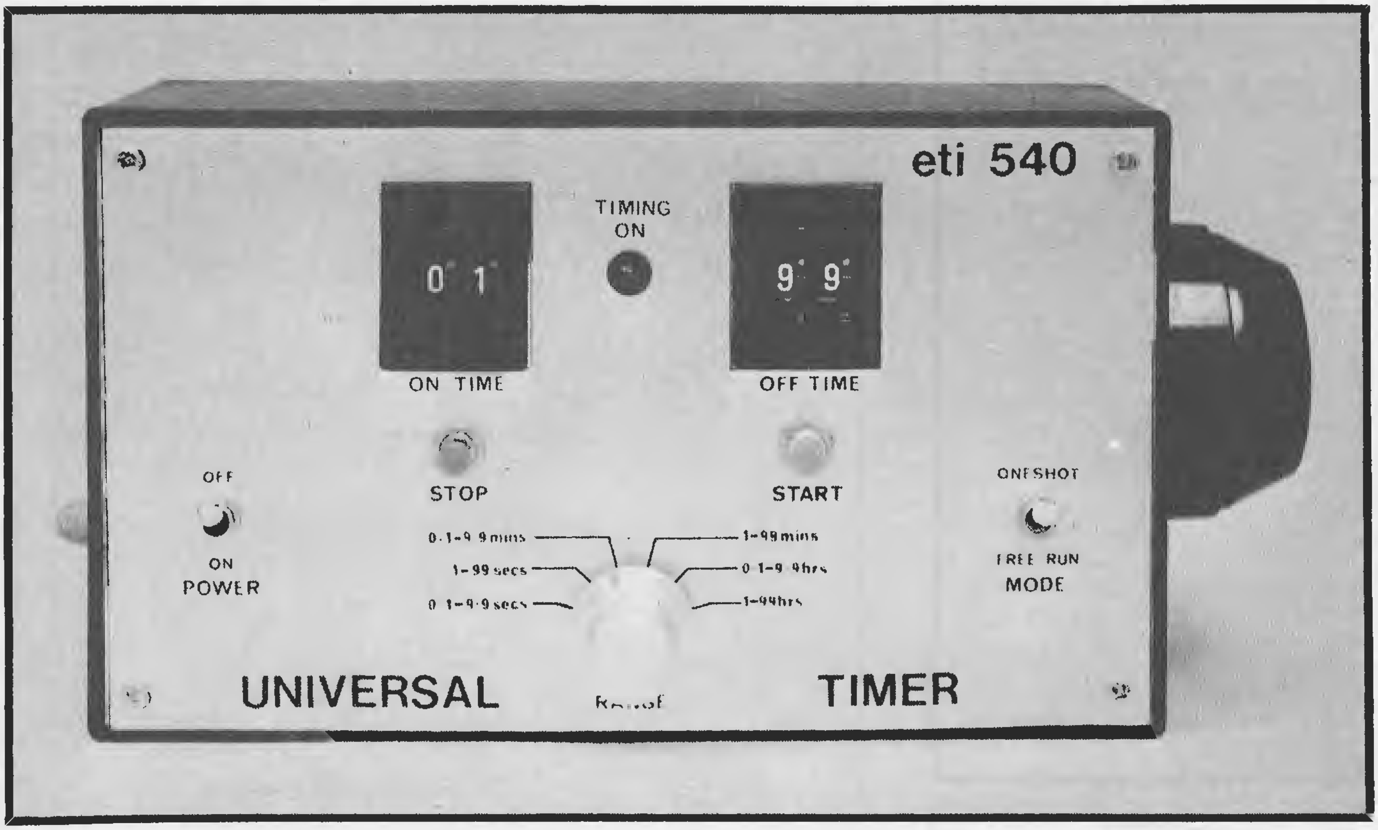
Probes

Probe construction and electrical contact is not nearly as critical as with most other biofeedback machines.

Commercial GSR machines use a pad of soft steel wool which is held firmly onto the finger by a short length of Velcro strap (Band-Aids work fine!). However, any method ensuring a firm contact between probe leads and the fleshy part of the finger will do. One method which works very well is to bind tinned copper wire around a guitar finger pick (or solder to a steel pick). Two probe connections are of course required – one for each of the first two fingers.

Universal timer

One tenth of a second to 99 hours. Both on and off times programmable. Manual or automatic operation resettable at any time.



THE TIMING OF EVENTS and processes is becoming an ever-increasing necessity particularly in applications involving automation.

Unfortunately most timers are either specifically made for a particular application — and difficult to adapt to others — or have restricted timing range, accuracy and facilities.

The ETI Universal Timer described in this project is free of most such constraints. It is extremely flexible, accurate and versatile. Its timing range is from 0.1 seconds to 99 hours. Both 'on' and 'off' times can be programmed (for example 12 hours on and 47 hours off). It can be manually started, stopped, or reset at any time, can be set for automatic cycling or for single cycle operation. It may be triggered by an external source (light, sound or pressure transducer etc). Finally, as the unit is digital — the 50 Hz mains is used as the reference — timing accuracy is very high indeed, and a manual reset facility enables the timer to be synchronized with local time if so desired.

Clearly not all users will need all the facilities provided — so if the unit is required for a specific permanent use it is a simple matter just to leave out those ICs not required — several variations are described at the end of this project.

CONSTRUCTION

We strongly recommend that this unit be assembled using the printed circuit board shown.

Begin construction by fitting the links to the board as shown on the component overlay. Note that there are two points labelled 'a' and two points labelled 'b'. Link 'a' to 'a' and 'b' to 'b' using insulated hook-up wire routed on the copper side of the board.

Mount the resistors to the board followed by the diodes, transistors, capacitors and finally the ICs. Take particular care to ensure that all the polarized components are orientated correctly — especially the integrated circuits.

Wires should now be attached to the board for later connection to the front panel switches. We used rainbow cable for the connections to the thumb-wheel switches as this makes the wiring easier and also helps to keep the wiring tidy. Mount the printed-circuit board into the case and mount the power outlet socket. Assemble the switches to the front panel and then interconnect the printed-circuit board, front panel and power socket in accordance with the interconnection diagram.

Finally after wiring the 240 Vac power circuitry insulate all 240 V terminals with tape to ensure that there is no risk of personal contact when fault finding is required at any later date.

CUSTOMIZING

The unit need not necessarily be built in its complete form and many different modifications are possible to lessen the cost of the unit when it is to be used for one particular application only. The modifications required for a number of specific applications are described below.

Specific fixed time — delete selector switches SW3 to SW6, and replace by wiring links from the appropriate outputs of IC4 and IC5 to the inputs of IC6/1 and IC6/2 respectively. The range switch may also be omitted by installing a link between the appropriate output of IC1 to IC3 and pin 13 of IC4.

Single shot operation — connect both inputs of IC6/2 to ground and omit switches SW5 and SW6.

Timing 99 hours or less — omit IC3 and connect inputs of IC7/3 and IC7/4 to ground.

Timing 99 seconds or less — omit IC2, IC3 and IC7.

External triggering — simplest way is a relay contact in parallel with start or stop button.

SPECIFICATION ETI 540

MODES

Freerun
On/off (note 1)
One shot
Manual override (note 2)

TIMING RANGE

0.1 seconds to 99 hours (note 3)

ACCURACY

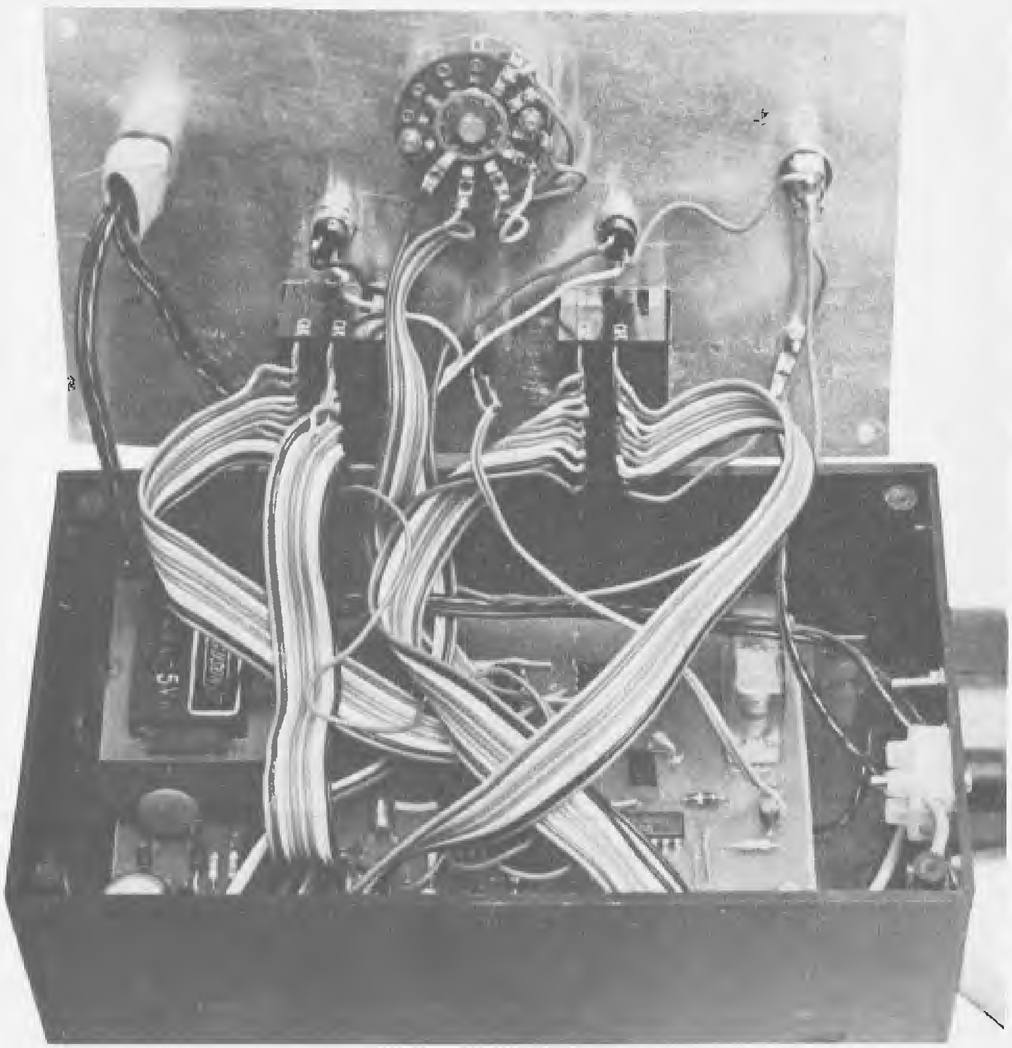
Mains synchronized

OUTPUT

240 volts ac relay switched

Note 1. Both on and off times are variable independently.
Note 2. Unit may be stopped or started at any time. If the appropriate button is pressed whilst in the same mode the timing is recommenced.
Note 3. Timing is adjustable by a common coarse control which gives ranges having a full scale of 9.9 seconds, 9.9 minutes, 99 minutes, 9.9 hours and 99 hours. Each range is adjustable from 1 to 99 that is one second on and 99 seconds off is possible whereas one second on and two minutes off is not (different coarse range is required).

The main consideration when making any changes is that the logic is CMOS and any unused inputs must be connected to ground or to +12 volts to prevent damage to the IC (which may overheat with unconnected inputs).



Universal timer

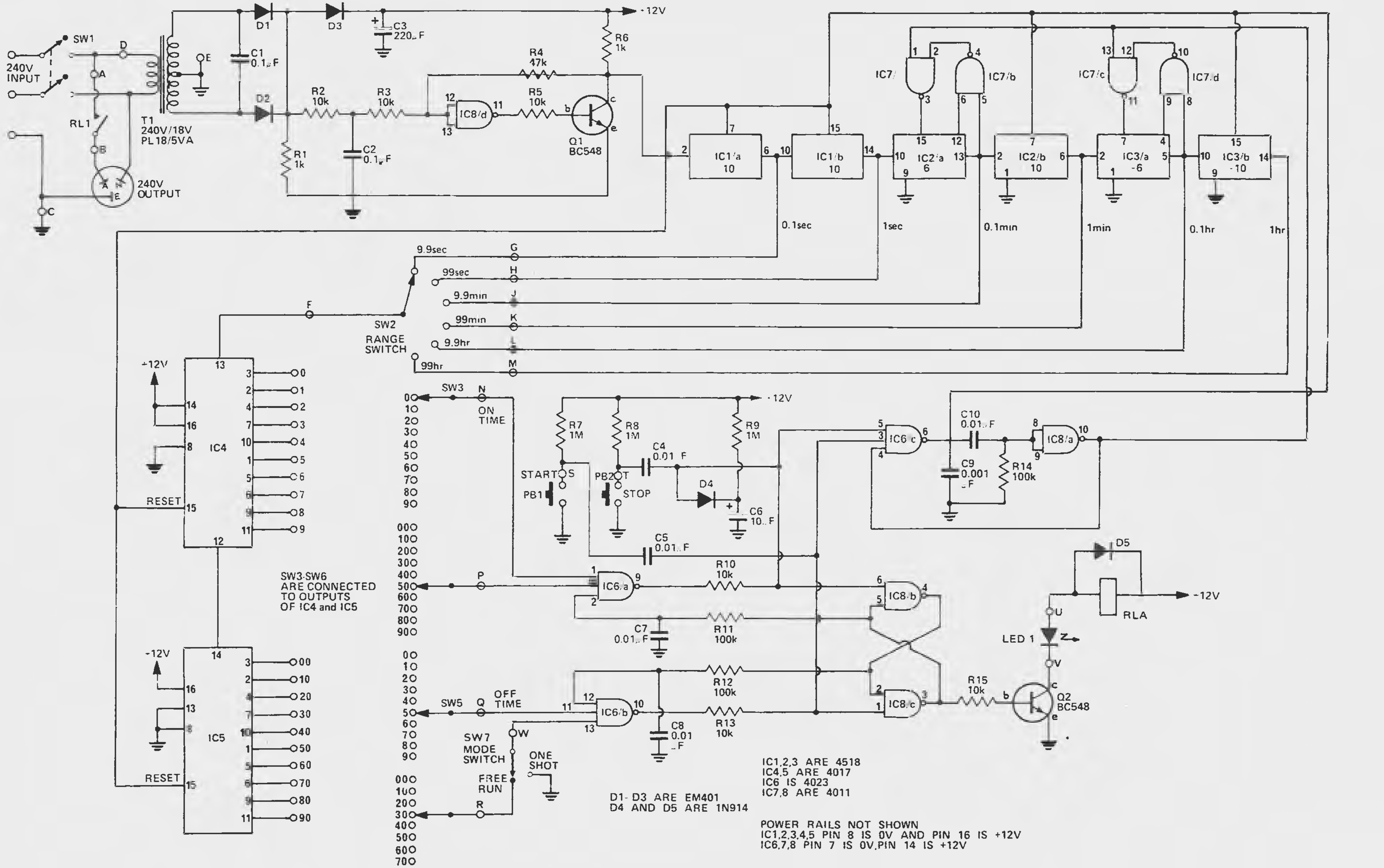


Fig. 1. Circuit diagram of the complete timer.

HOW IT WORKS – ETI 540

THE 240 Vac is reduced to 12 Vdc by transformer T1 and diodes D1 to D3. Diode D3 isolates the smoothing capacitor C3 from the rectifiers and therefore 100 Hz ripple appears across R1. This waveform is used for the basic timing reference for the timer. To operate the counting ICs reliably a very fast rise-time waveform is required at the clock input. This is obtained by feeding the 100 Hz to a Schmitt formed by IC8/1 and Q1. Capacitor C2 is included to prevent the control tones superimposed on the mains for the control of hot-water services from upsetting the timing accuracy.

The 100 Hz from the Schmitt trigger is divided by 10 by IC1/1 to give a 10 Hz or 0.1 second output – the first required. Note that due to the low frequencies involved from now on the outputs will be referred to as time periods not as frequencies. A second divide by ten stage is used to give a one second output. A division by six is then performed by IC2/1 with IC7/1 and IC7/2 being used to decode the six count and reset the counter. This gives the one minute (or sixty second) period required. Further divisions of 10,6 and 10 are used to provide the six outputs required to select periods from 0.1 seconds to one hour.

One of these six outputs is selected by the range switch SW2 and is fed to a 4017 IC – the first of a pair of decade counters which have ten decoded outputs. The ten outputs of each IC go high in turn for one clock period each. As the two 4017 ICs are in series, a total division of 100 is obtainable. We have labelled the outputs of IC4 and IC5 as 0 to 9 and 00 to 90 respectively. IC4 is triggered by the clock enable as negative edge triggering is required. The second IC is clocked normally by the carry output from IC4.

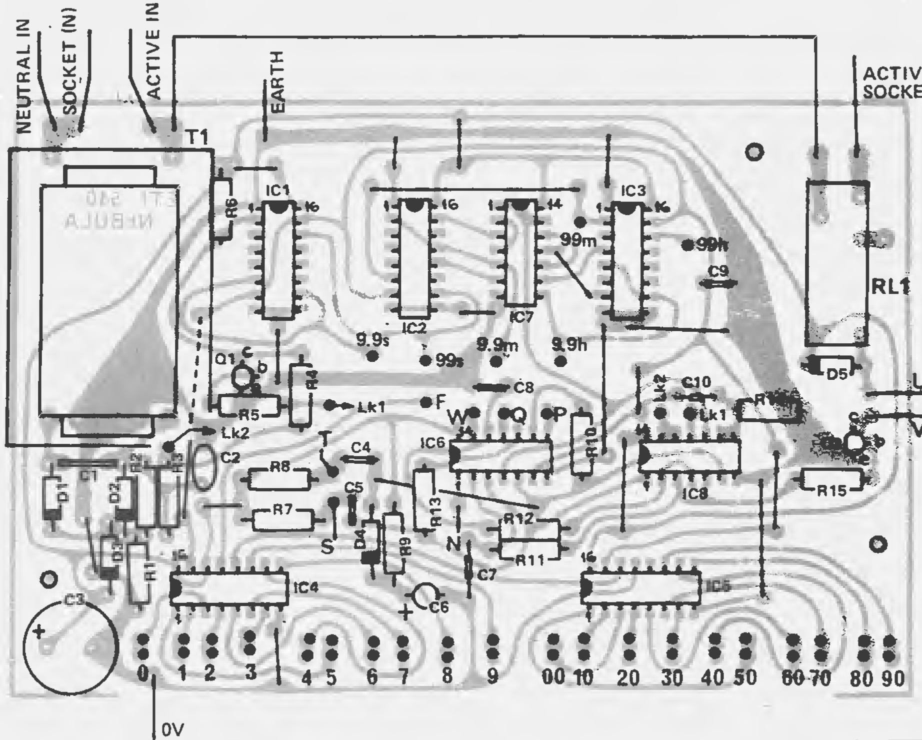
We pause at this point to go straight to the control output which is via a relay RL1, this in turn being controlled by the flip-flop made up of IC8/2 and IC8/3. This flip-flop can be controlled either manually by PB1 (manual on) and PB2 (manual off) or automatically by IC6/1 and IC6/2. To toggle the flip-flop automatically the output of either IC6/1 or IC6/2 must be low and for the output to be low the three inputs must all be high. This occurs only when the number selected by SW3 and SW4 (for IC6/1) and SW5 and SW6 (for IC6/2) is held by the counters IC4 and IC5 and the third input from the flip-flop is used to ensure that the off-time of the relay is controlled only by the off-time selector switches. A small time delay is incorporated in the signal back from the flip-flop to avoid the ambiguity that could arise with equal times.

If the output of either IC6/1 or IC6/2 goes low the monostable formed by IC6/3 and IC6/4 is triggered and its resultant output is used to reset all the counters to zero. This reset also occurs if either of the manual push buttons is pressed. The push buttons are coupled into the logic by capacitors so that only the initial part of the press actuates the logic and there is therefore no dependency on the length of time for which the button is pressed.

The sequence of events is as follows assuming that initially the switches are set for 25 seconds on and 14 seconds off.

On first switch-on C6 ensures that the flip-flop is toggled into the off state and also that the counters are all reset to zero. The control inputs from the flip-flop to IC6/1 and IC6/2 are low and high respectively. Therefore until the flip-flop changes state only IC6/2 can have the three high inputs necessary to provide a low at the output. Meanwhile the counters IC4 and IC5 are counting up at the rate of one count per second. After 14 seconds all three inputs to IC6/2 are high and the output goes low toggling the flip-flop. The monostable is then triggered and all counters are reset to zero. This removes the three high inputs to IC6/2 and the output goes high again. The pulse output of IC6/2 is very narrow and is about a microsecond long. As the flip-flop has now changed state the relay has been closed and IC6/1 has been enabled (control input to pin 2 now high). After 25 seconds all the inputs to IC6/1 are high and the same procedure as before resets the counters and changes the state of the flip-flop.

In the one-shot mode of operation one input of the off timer is grounded and the off time procedure is effectively disabled. The only way that the timer can now start is for the manual start button to be pressed.



PARTS LIST – ETI 540

Resistors

R1	–	1 k	½ W	5%
R2,3	–	10 k	"	"
R4	–	47 k	"	"
R5	–	10 k	"	"
R6	–	1 k	"	"
R7-R9	–	1 M	"	"
R10	–	10 k	"	"
R11.12	–	100 k	"	"
R13	–	10 k	"	"
R14	–	100 k	"	"
R15	–	10 k	"	"

Capacitors

C1	–	0.1 μF 50 V disc ceramic
C2	–	0.1 μF polyester
C3	–	220 μF 16 V electro
C4,5	–	0.01 μF polyester
C6	–	10 μF 16 V electro
C7,8	–	0.01 μF polyester
C9	–	0.001 μF "
C10	–	0.01 μF "

Diodes

D1-D3	–	EM401 or similar
D4, 5	–	IN914 or similar
LED 1	–	RL4850 or similar

Transistors

Q1,Q2 – BC548 or similar

Integrated Circuits

IC1-IC3	–	4518
IC4,5	–	4017
IC6	–	4023
IC7,8	–	4011

Transformer 240 V/18 V CT PL18/5 VA
pc Board ETI 540
Relay, single pole 280 Ω coil 240 V 5A contact

Switches

SW1	double pole toggle switch
SW2	single pole 6 position rotary
SW3-6	single pole 10 position *
SW7	single pole toggle
PB1,2	single pole "make" push buttons

* C&K 321100000 is a 2 section Thumbwheel switch forming SW3 + 4 and SW5 + 6 (2 required)
Case plastic 196 x 113 x 60 mm
power cord, plug and clamp
3 pin power outlet socket

Universal timer

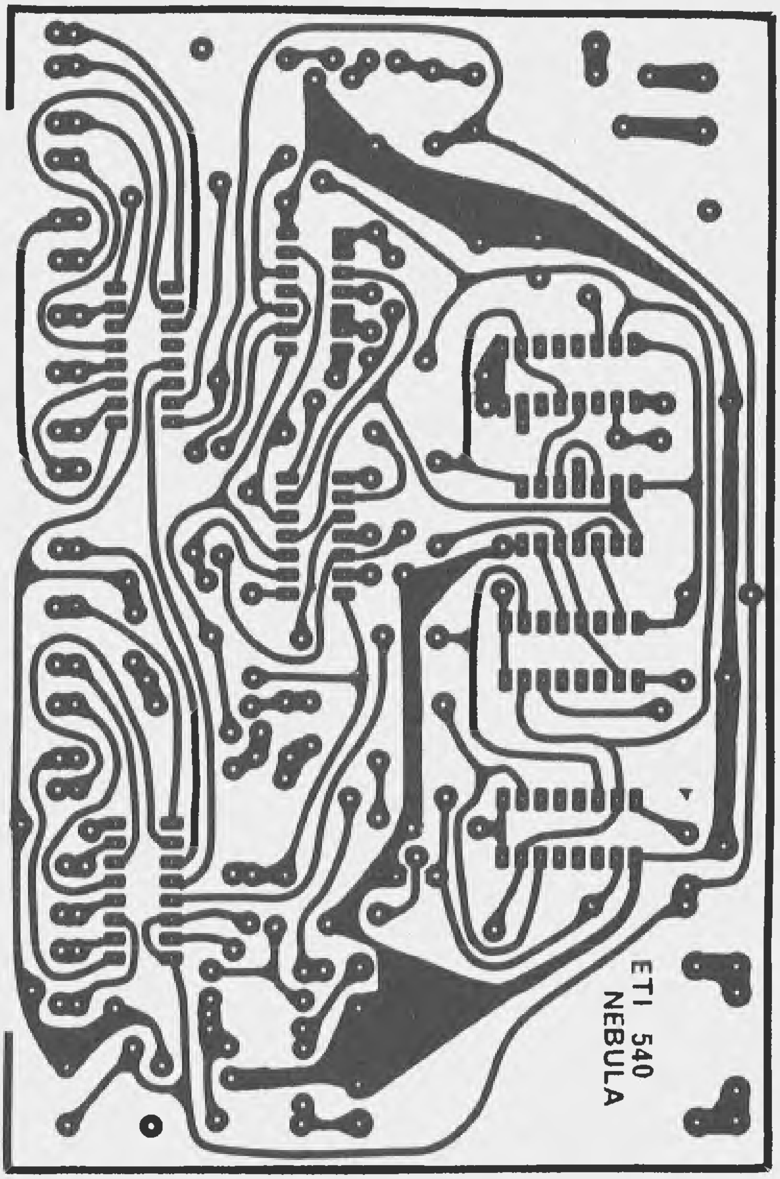


Fig. 4. Printed-Circuit board layout for the timer. Full size 153 x 100 mm.

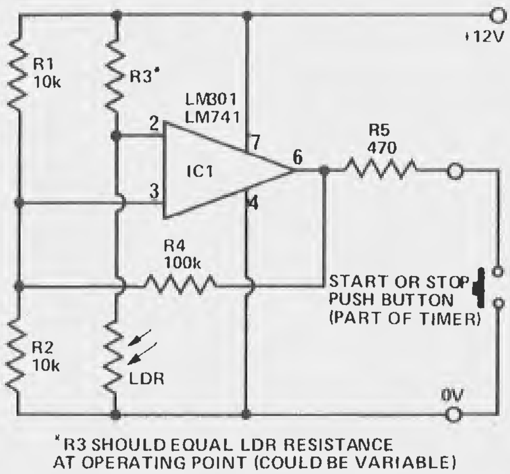
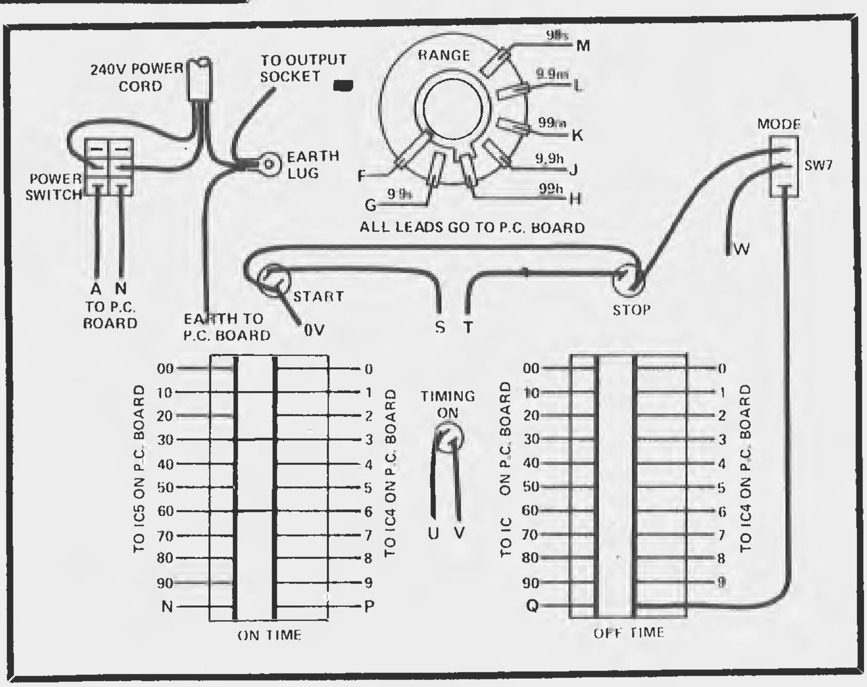


Fig. 6. For triggering timer from a change in light level this circuit will be found suitable.

Note: For front panel artwork see page 92.

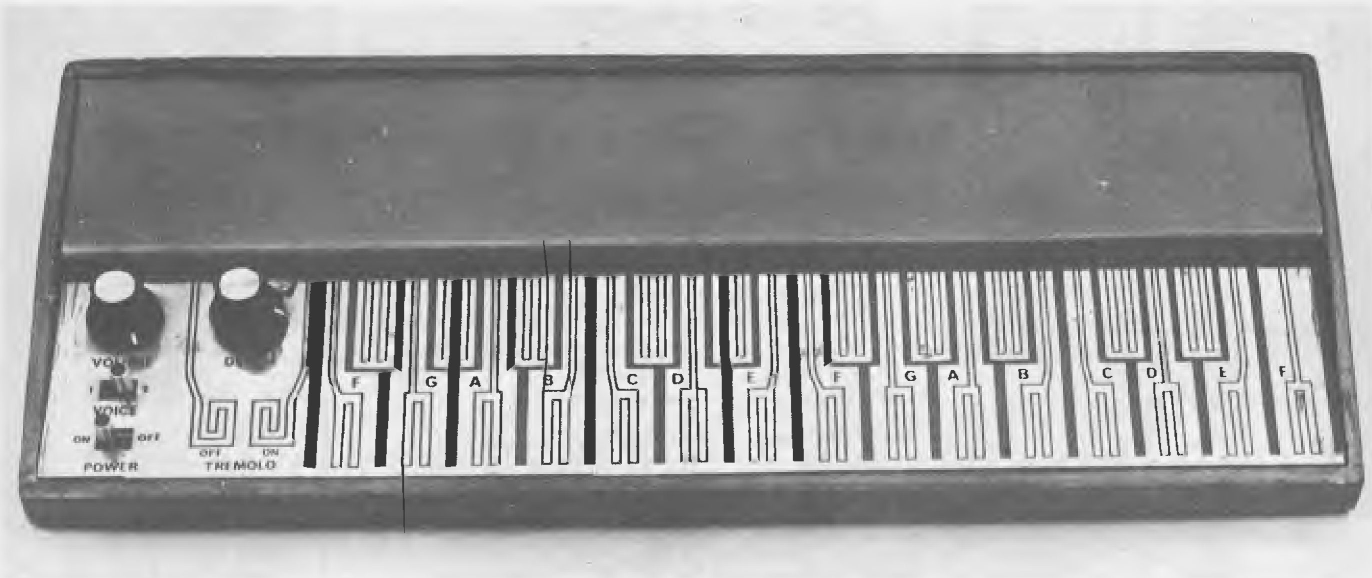
Fig. 3. Interconnection diagram. ▶



Give your Universal Timer a professional look! Finished Scotchcal panels are available from ETI for $3.00 – plus self-addressed stamped envelope at least 120 mm x 200 mm. Please make cheques or postal orders payable to 'Scotchcal Offer' not Electronics Today.

ETI MINI-ORGAN

With all the electronics on one pc board this organ is easy to build yet has features like touch keyboard, variable tremolo, two voices and a full two-octave range.



AN ELECTRONIC ORGAN IS A fascinating instrument which these days seems to be rapidly assuming the position in the home once occupied by the piano. Modern organs are, however, very expensive, ranging from around $1000 to $4000 – a price which puts them beyond the reach of most people. Lower down the scale in cost and performance are chord organs which although still polyphonic are fairly limited reed type instruments operated by a small blower. The name chord organ comes from the fact that the bass accompaniment is by means of buttons which generate the appropriate chord. Such instruments still may cost several hundred dollars.

The cheapest possible organ is the so called monophonic organ (only one note can be played at a time) which is usually little more than pocket sized and is played with a stylus.

Such an organ was described in the May 1974 issue of ETI and was enormously popular with our younger readers. So popular that we have been asked to update and improve this instrument without adding to the cost too greatly.

The first obvious improvement required is to devise a better keyboard arrangement as the stylus operation can only be described as somewhat of a nuisance. However the $100 of a full keyboard cost cannot be justified. As can be seen from the photographs the new keyboard is still of the touch type but has now been designed so that the organ is played simply by touching the appropriate key, as in a full scale instrument. Tremolo is also provided and this too is switched on and off by means of touch switches and a control is provided to adjust tremolo depth.

The next improvement is in the accuracy of the tuning, which in the previous instrument varied over the keyboard due to the one-only resistor used to increment between each note. In our new version tuning over the keyboard is much improved by using two resistors, where necessary in series or parallel, to obtain the nearest possible to the correct value of resistance. Finally the instrument is provided with two voices or stops which add greatly to the variety of the music which can be produced.

This little organ is relatively inexpensive to build, should provide a great deal of enjoyment and is musically and electronically educational.

Main text continues on page 76

ETI MINI-ORGAN

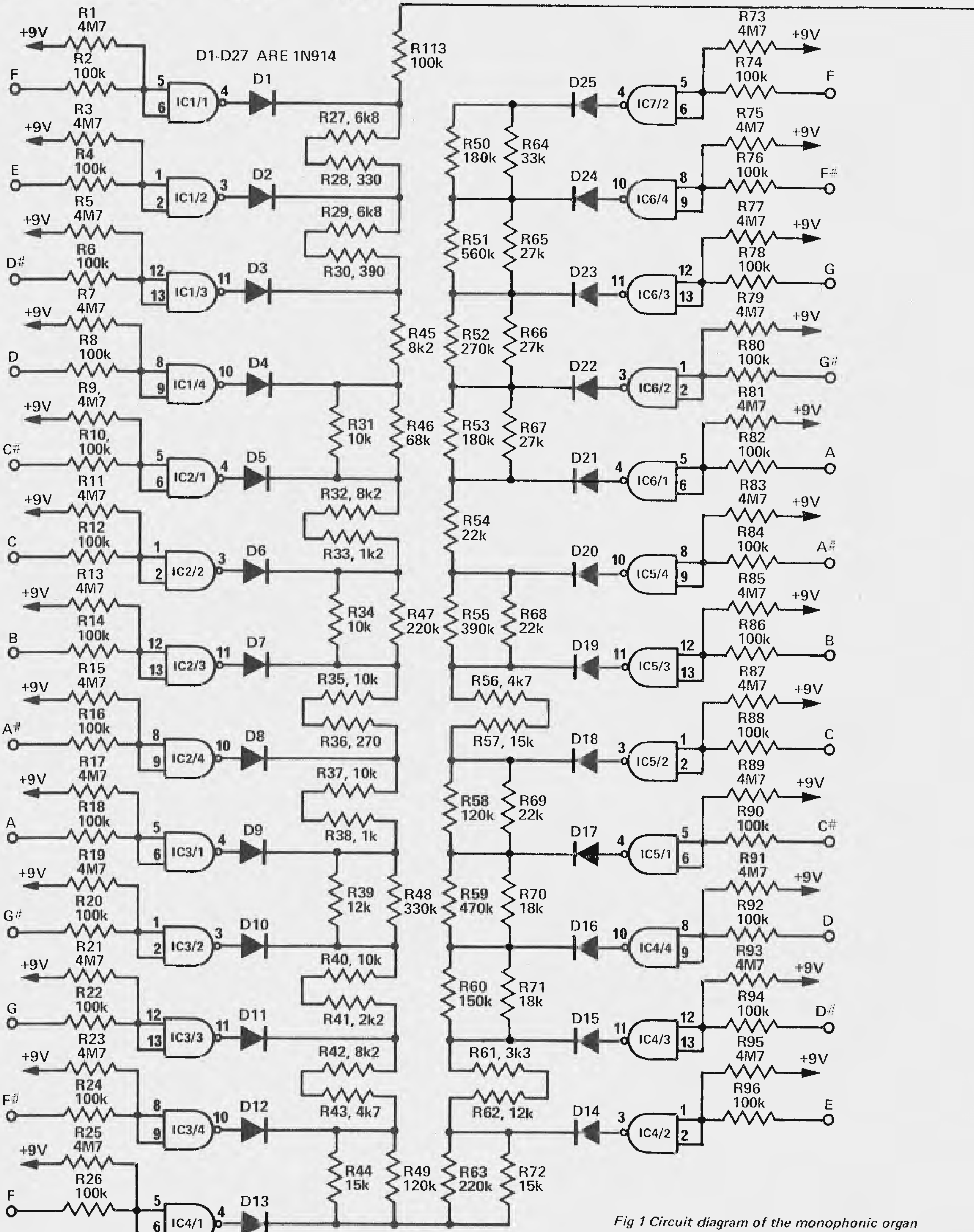
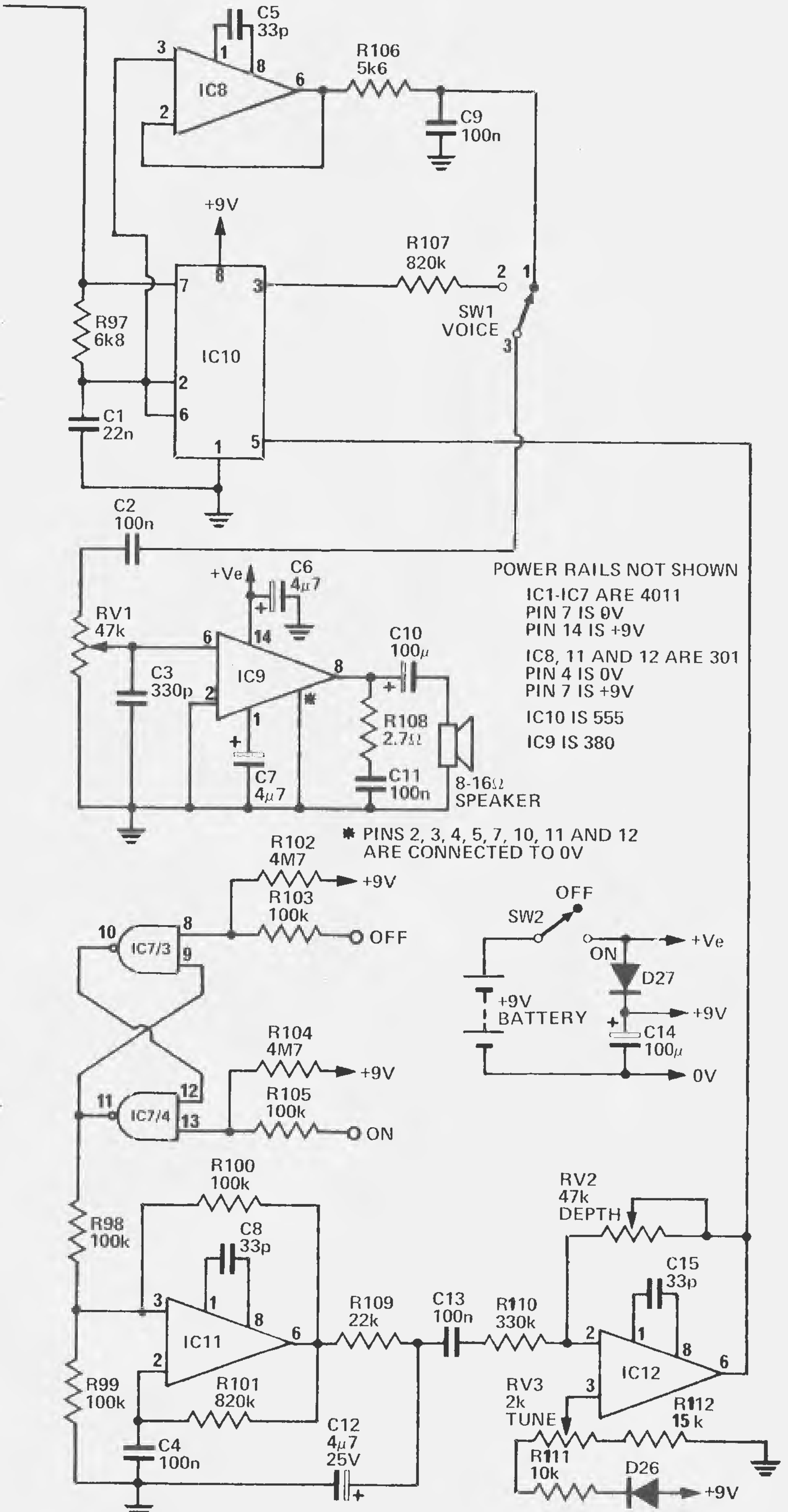


Fig 1 Circuit diagram of the monophonic organ



How it works ETI 602

Operation of the organ will be described by considering separately the five sections of which it is composed. These are:—

- (a) Keyboard
- (b) Oscillator
- (c) Filter
- (d) Output amplifier
- (e) Tremolo circuit

(a) Keyboard. Unlike the previous organ the keyboard is operated by the contact resistance of the finger and not by a probe. Each key has a CMOS gate associated with it where both inputs to the gate are connected together and to the positive supply via a 4.7 megohm resistor. When the key is touched the inputs of the gate are pulled low (0V) via the 100 k resistor causing the output of the gate to go high. This pulls the corresponding point in the resistor chain high via the diode. Thus by selecting and touching different keys we connect various amounts of resistance between pins 2 and 6 of the 555 oscillator and the positive supply, thus enabling it and varying the frequency determining time constant circuit.

(b) The Oscillator. The oscillator is based on a 555 timer IC. The capacitor C1 is charged up via a section of the resistor chain (as by the keyboard) together with the resistor R113. When the voltage at pins 2 and 6 reaches that set at pin 5, the capacitor is discharged rapidly via R97 and an internal transistor connected to pin 7 of the 555. When the voltage across C1 has dropped to half that set at pin 5, the internal transistor turns off and the capacitor is allowed to charge up again — thus repeating the cycle and generating a sawtooth waveform across the capacitor. This waveform has a high harmonic content but is generated at a high-impedance point. A unity gain buffer is therefore used (IC8) to prevent this output from being loaded by the following circuitry. A second output of a narrow pulse waveform is available at pin 3 of the 555 and this is used to generate a second voice for the instrument.

(c) Filter. A number of different filters were tried but from a cost point of view it was difficult to justify anything more than a simple RC filter on the sawtooth which gives quite a pleasant flute-like effect. As the narrow pulse train sounds somewhat similar to strings

Continued on page 75

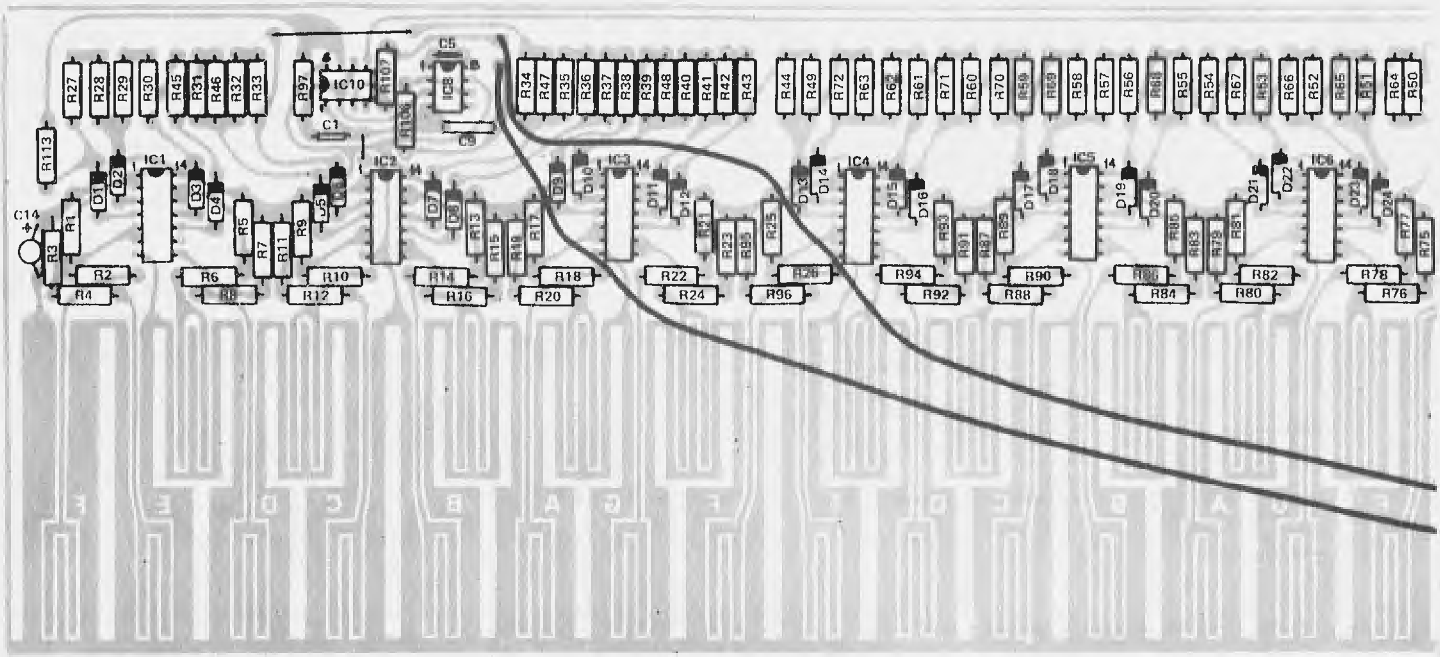


Fig 2 Component overlay and interconnection diagram

Parts List ETI 602

Resistors all ½W 5%

R1,3,5,7	4M7
R9,11,13	4M7
R15,17,19	4M7
R21,23,25	4M7
R2,4,6,8	100k
R10,12,14	100k
R16,18,20	100k
R22,24,26	100k
R27	6k8
R28	330
R29	6k8
R30	390
R31	10k
R32	8k2
R33	1k2
R34,35	10k
R36	270
R37	10k
R38	1k
R39	12k
R40	10k
R41	2k2
R42	8k2
R43	4k7
R44	15k
R45	8k2
R46	68k
R47	220k
R48	330k
R49	120k
R50	180k
R51	560k
R52	270k
R53	180k
R54	22k
R55	390k
R56	4k7
R57	15k
R58	120k
R59	470k
R60	150k
R61	3k3
R62	12k
R63	220k
R64	33k
R65,66,67	27k
R68,69	22k
R70,71	18k
R72	15k
R73,75,77	4M7
R79,81,83	4M7
R85,87,89	4M7
R91,93,95	4M7
R74,76,78	100k
R80,82,84	100k
R86,88,90	100k
R92,94,96	100k
R97	6k8
R98,99,100	100k
R101	820k
R102	4M7
R103	100k
R104	4M7
R105	100k
R106	5k6
R107	820k
R108	2.7Ω
R109	22k
R110	330k
R111	10k
R112	15k

Potentiometers

RV1	47k log rotary
RV2	47k log rotary
RV3	2k trim

Capacitors

C1	22n polyester
C2	100n polyester
C3	330p ceramic
C4	100n polyester
C5	33p ceramic
C6,7	4μ7 25V electro
C8	33p ceramic
C9	100n polyester
C10	100μ 16V electro
C11	100n polyester
C12	4μ7 25V electro
C13	100n polyester
C14	100μ 16V electro
C15	33p ceramic

Semiconductors

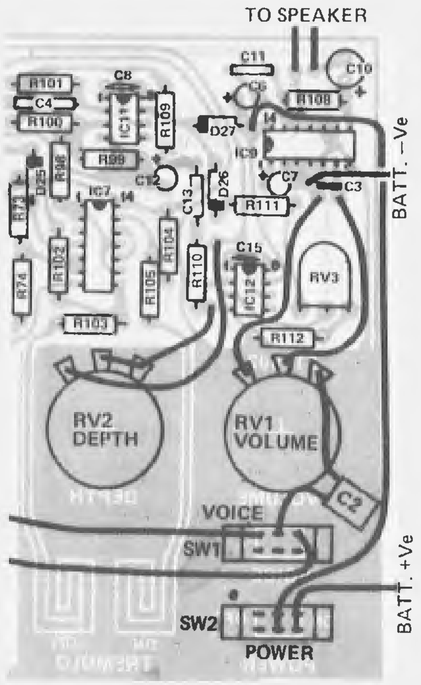
D1-D27	1N914 or similar
IC1 – IC7	4011 (CMOS)
IC 8,11,12*	LM301 or 741
IC9	LM380,SL60745
IC10	NE555

*if 741s are used delete C5,8,15

Miscellaneous

SW1,2	single pole, 2 position slide switches

PC board ETI 602
Two knobs
6 way AA size battery holder
Small 8 or 16 ohm speaker
battery clip
case to suit



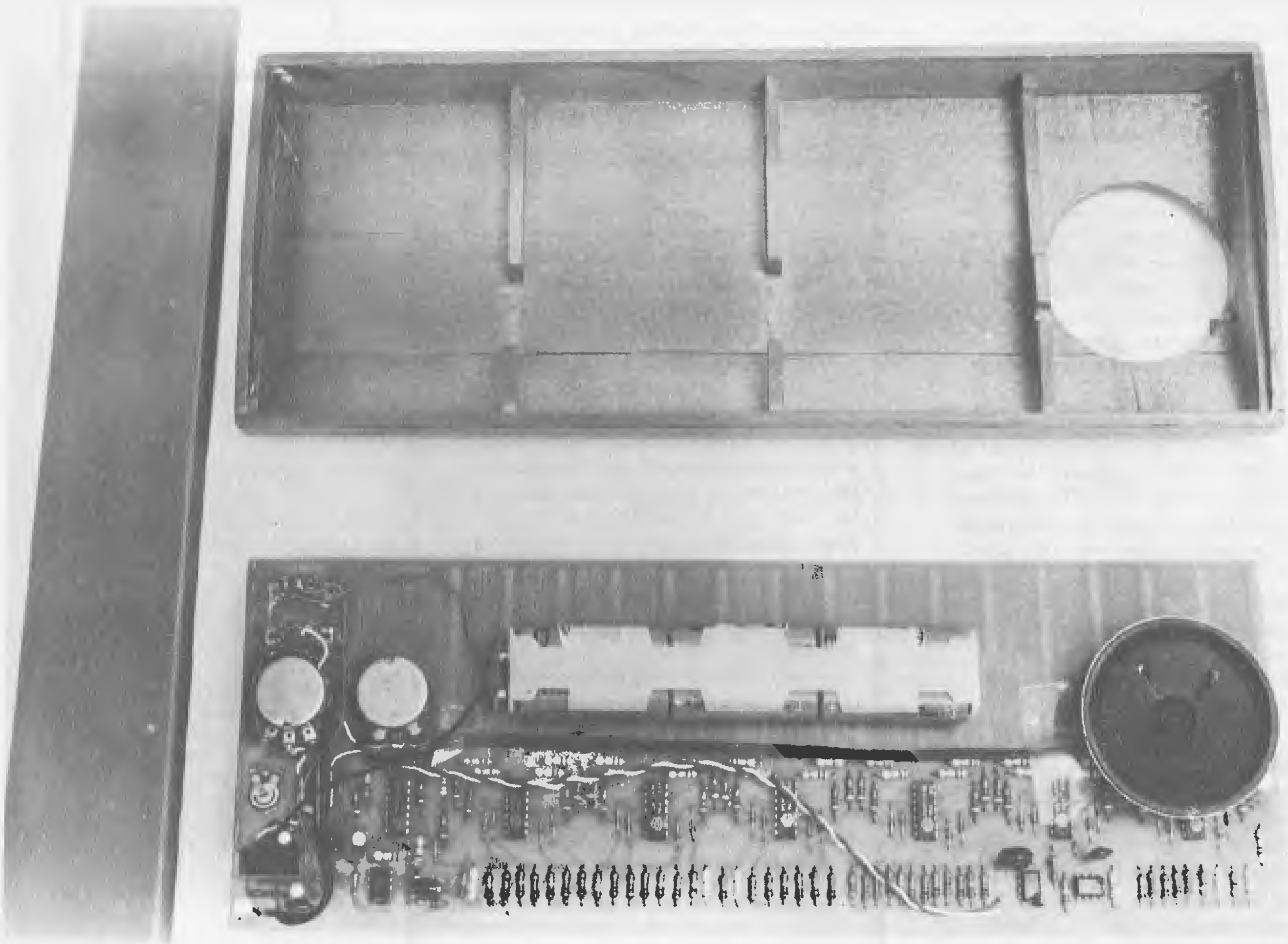
How it Works, Continued from page 73

it is merely attenuated to match the level of the filtered sawtooth.

(d) The Output Amplifier. The loudspeaker is driven by an LM380. Volume control is provided by means of potentiometers RV1 and the required voice is selected by means of switch SW1. The LM380 should be fitted with heatsink fins as detailed in the construction.

(e) The Tremolo Circuit. Tremolo is produced by means of a low frequency oscillator running at approximately 8 Hz (IC11). The oscillator can be turned on and off by means of the flip flop formed by gates IC7/3 and IC7/4. This flip flop is set to the 'on' or 'off' mode by means of touch switches which operate in exactly the same manner as the main keyboard. To increase tremolo frequency decrease R101 and vice versa.

The output from the tremolo oscillator is filtered by C12 and R109 to give a smoother waveform and the resultant waveform buffered by IC12. The gain of IC12 is adjustable by means of RV2 and this control therefore adjusts the depth of the tremolo modulation. The potentiometer RV3 is a trim potentiometer which effectively sets the output from IC12 to pin 5 of the 555 and thus the frequency of the organ. If it is required to shift the keyboard up or down an octave or so this may be done by changing the value of C1 by a factor of two. If the keyboard tuning is found to be skewed (when tuned correctly at the centre one end of the keyboard is low whilst the other is high) this may be cured by changing the value of R97. If it is sharp at the low end decrease R97 while if flat at the low end increase R97.



Design Features

As said earlier the major improvement in the organ is in the implementation of the keyboard by means of a finger touch system rather than the probe type used in the previous organ. This means that some electronics must be associated with each key to detect that it has been touched. Touch control is usually effected by the capacitive, resistive or 50 Hz injection methods, Whilst the capacitive method is the best of these it is also the most expensive and for this reason is not used. The 50 Hz injection method is also complex and thus the resistive method was considered to be the only practical way from a cost point of view.

As the keyboard is now played by the finger it also needs to be larger than in the original organ although still not quite as large as a full-size keyboard.

In the original organ an OM 802 was used as the tone oscillator. This was replaced by a 555 timer IC as this is cheaper and easier to use. The 555 has two outputs which can be used, a sawtooth wave and a narrow pulse. Both of these outputs are used in our design to provide different voices for the instrument. The sawtooth is filtered by means of a simple RC filter to remove some of the harshness due to the harmonic structure and the resultant voice has a rich flute-like sound. The pulse output is matched in level to the sawtooth by means of a resistive attenuator but is otherwise unfiltered. This voice has a string-like sound.

Filtering has been kept very simple, again from a cost point of view. If the constructor desires he may experiment with different filters in order to achieve different sounds. With conventional organs the stop-filtering is done for every octave of the organ to prevent undue tone and level changes at different frequencies. With the two octave span of this organ some change in tone and level must be accepted over the range of the keyboard when using simple filters.

As attenuating filters are used in the organ plenty of gain is required in the audio stage and for this reason an LM380 is used in the audio output stage to drive the loudspeaker.

Construction

The keyboard pattern is etched directly onto the printed-circuit board which also carries the rest of the electronics. As the copper of the keyboard would rapidly tarnish when continuously being touched with the finger it is necessary for the board to be either tinned or protected with some other plating process that will prevent tarnishing.

Commence construction by mounting the LM380 into position and then fit small heatsink fins, as shown in the photograph, to either side of the IC. Solder them to pins 3,4,5 on one side and pins 10,11 and 12 on the other. This should be done first as there is little room in this area of the board once other components are in position. Fit the two wire links and assemble the low-height components to the board as shown on the overlay.

Mount the remaining ICs last of all and take particular care not to handle the CMOS ICs excessively before insertion. Check the polarities of polarised components such as ICs, capacitors and diodes before soldering them into position.

To avoid having screws showing on the keyboard we glued the two switches into position with five-minute epoxy. Use a piece of printed-circuit board or metal behind each mounting hole to obtain extra glueing surface and extra strength. Mount the potentiometers and wire the complete board as detailed in the overlay diagram.

The complete unit should now be tested to ensure that all notes and functions are operating correctly before mounting into a suitable cabinet. ●

Frequency of Notes used

F	698.5
E	659.3
D#	622.3
D	587.3
C#	554.4
C	523.3
B	493.9
A#	466.2
A	440.0
G#	415.3
G	392.0
F#	370.0
F	349.2
E	329.6
D#	311.1
D	293.7
C#	277.2
C	261.6
B	246.9
A#	233.1
A	220.0
G#	207.7
G	196.0
F#	185.0
F	174.6

Playing the organ.

Although the new organ is played with the fingers as with a full instrument there are a few small playing differences which should be kept in mind.

Firstly the instrument is monophonic. That is, if two notes are touched simultaneously only the higher note will sound. Secondly, the fingers must be kept dry, as any moisture across a key will hold that note on when the finger is removed. If this does happen then the keyboard should be wiped with a clean dry rag. In stubborn cases a little methylated spirits on the rag will help.

Finally, it should be remembered that unlike a piano there is no "touch" to the instrument and hitting the key hard will not alter the sound. In this respect it is similar to a real organ and the player should get used to touching the keys smoothly and firmly with the flat part of the finger — not the extreme tip.

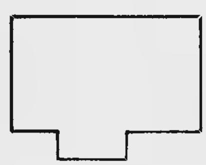


Fig 3
Details of heat sink shown full size, two required material tinplate or thin copper.

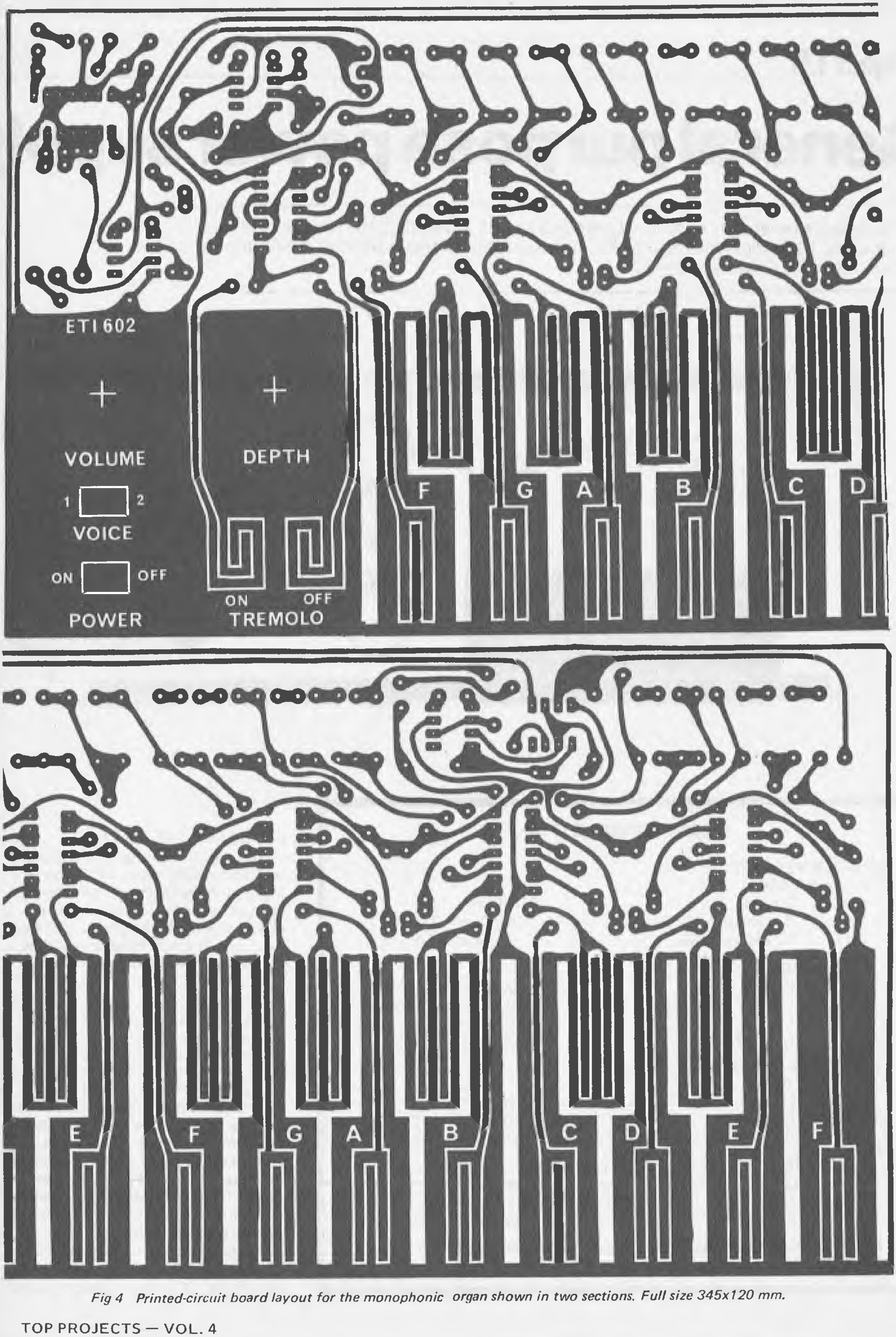
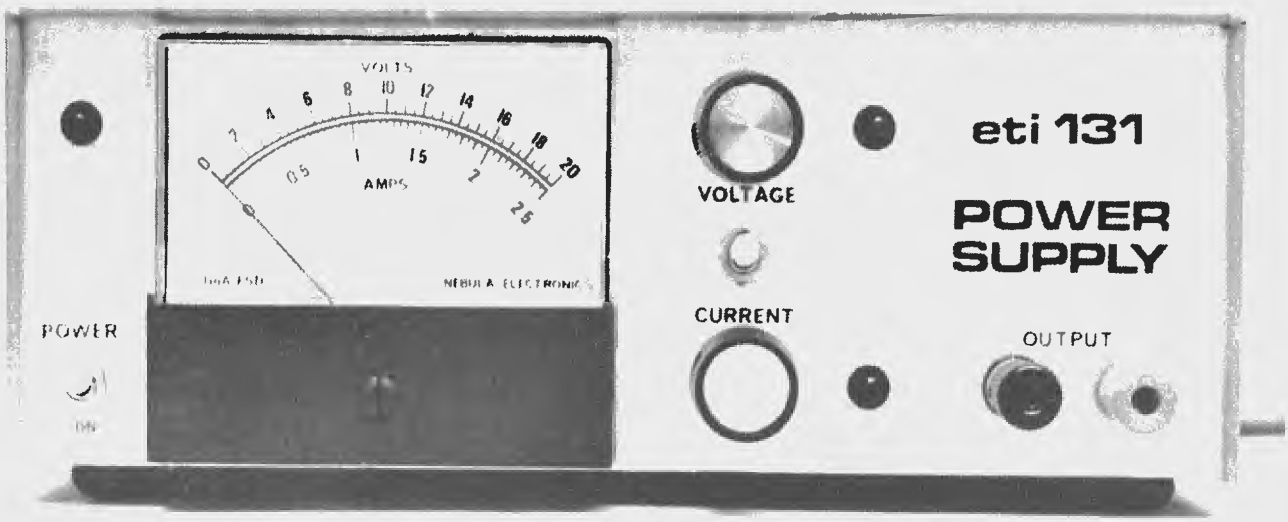


Fig 4 Printed-circuit board layout for the monophonic organ shown in two sections. Full size 345x120 mm.

Project 131

General purpose power supply

This versatile general purpose supply produces up to 2.5 amps from zero to 20 volts – or up to 1.25 amps from zero to 40 volts. Current limiting is adjustable over the entire range for either output option.



SPECIFICATION – ETI 131

20 VOLT VERSION	
VOLTAGE	
Output	0–20 volts
Regulation	<20 mV (0–2.5A)
Ripple and noise	< 1 mV at 2.5A
CURRENT	
Output	0–2.5A (up to 18 V) 0–2.0A (up to 20 V)
Limit	0–2.5A
Regulation	<10 mA (0–20 V)
40 VOLT VERSION	
VOLTAGE	
Output	0–40 V
Regulation	<20 mV (0–1.25A)
Ripple and noise	<1.5 mV at 1.25A
CURRENT	
Output	0–1.25A
Limit	0–1.25A
Regulation	<10 mA (0–40 V)

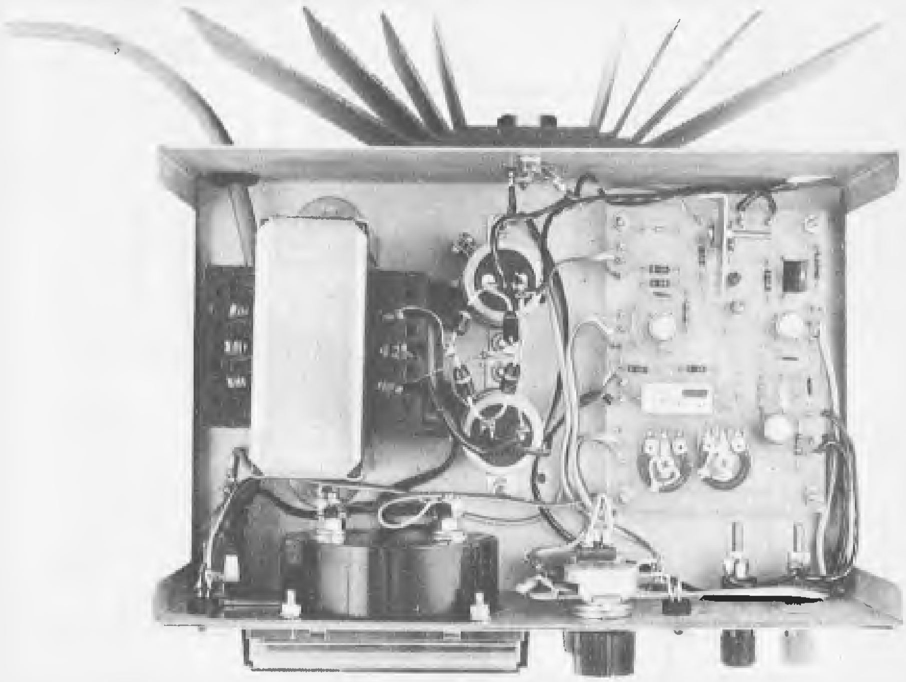
In both versions LEDs indicate voltage or current modes and the meter is switchable to read voltage or current.

AN IDEAL POWER SOURCE should supply a voltage which is adjustable over a wide range, and which remains at the set voltage regardless of line voltage or load variations. The supply should also be undamaged by a short circuit across its output and be capable of limiting the load current so that devices are not destroyed by fault conditions.

Two such supplies have previously been described in ETI. The first was a simple supply providing 0 to 15 volts at up to 750 mA. The second was a dual tracking supply providing ± 20 volts at up to one ampere. Both these supplies have been extremely popular, especially the simple one, and are still being built by many people. However there have been many requests for a supply having a greater output current capability than either of these previous designs could provide.

This project describes a supply that will provide 2.5 amperes at up to 18 volts (up to 20 volts at lower currents).

Alternately a few simple changes can make the supply provide up to 40 volts at 1.25 amperes. The supply voltage is settable between zero and the maximum available, and current limiting is also adjustable over the full range. The mode of operation of the supply is indicated by two LEDs. The one beside the voltage control knob indicates when the unit is in normal voltage-regulation mode and the one beside the current limit control indicates when the unit is in current-limit mode. In addition a large meter indicates the current or voltage output as selected by a switch.



Inside view of the completed 40 volt power supply. Note how the heatsink is mounted to the rear of the unit.

DESIGN FEATURES.

During our initial design stages we looked at various types of regulator and the advantages and disadvantages of each in order to choose the one which would give the best cost-effective performance. The respective methods and their characteristics may be summarized as follows.

The shunt regulator. This design is suitable mainly for low-power supplies – up to 10 to 15 watts. It has good regulation and is inherently short-circuit proof but dissipates the full amount of power it is capable of handling under no-load conditions.

The series regulator. This regulator is suitable for medium-power supplies up to about 50 watts. It can and is used for higher power supplies, but heat dissipation can be a problem especially at very high current with low output voltages. Regulation is good, there is little output noise and the cost is relatively low.

SCR regulator. Suitable for medium to high power applications, this regulator has low power dissipation, but the output ripple and response time are not as good as those of a series regulator.

SCR preregulator and series regulator. The best characteristics of the SCR and series regulators are combined with this type of supply which is used for medium to high-power applications. An SCR pre-regulator is used to obtain a roughly regulated supply about five volts higher than required, followed by a suitable series regulator. This minimizes power loss in the series regulator. It is however more expensive to build.

Switching regulator. Also used for medium to high-power applications, this method gives reasonable regulation and low power dissipation in the regulator but is expensive to build and has a high frequency ripple on the output.

Switched-mode power supply.

The most efficient method of all, this regulator rectifies the mains to run an inverter at 20 kHz or more. To reduce or increase the voltage an inexpensive ferrite transformer is used, the output of which is rectified and filtered to obtain the desired supply. Line regulation is good but it has the disadvantage that it cannot easily be used as a variable supply as it is only adjustable over a very small range.

OUR OWN DESIGN

Our original design concept was for a supply of up to 20 volts at 5 to 10 amps output. However, in the light of the types of regulator available, and the costs, it was decided to limit the current to about 2.5 amps. This allowed us to use a series regulator – the most cost-effective design. Good regulation was required, together with variable-current limit, and it was also specified that the supply would be useable down to virtually zero volts. To obtain the last requirement a negative supply rail or a comparator that will operate with its inputs at zero volts is required.

Rather than use a negative supply

Rear view of the heatsink showing how it and the transistor are mounted.

General purpose power supply

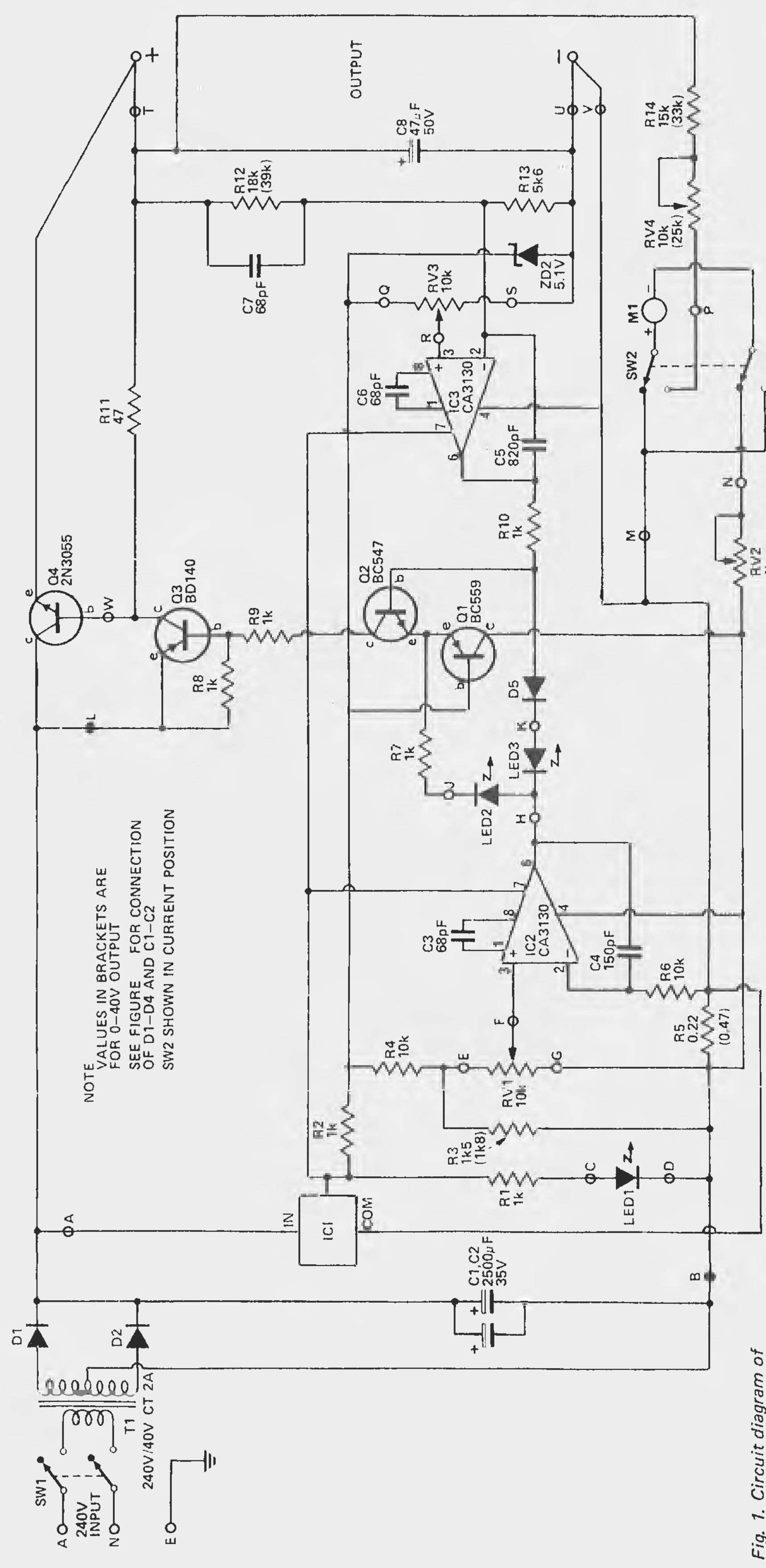


Fig. 1. Circuit diagram of the complete power supply 20 volt 2.5 ampere version.

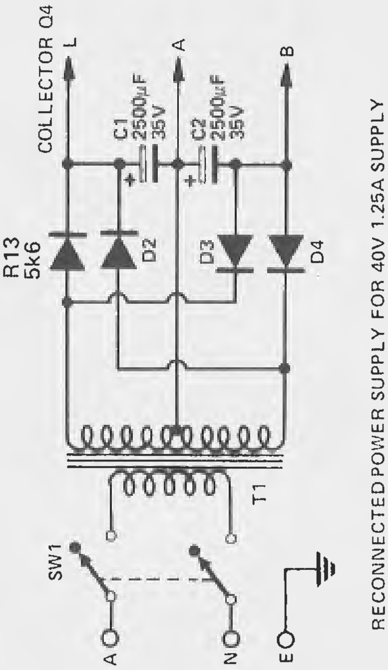


Fig. 2. Alternative rectifier and filter capacitor connections required for 40 volt, 1.25 ampere version.

HOW IT WORKS – ETI 131.

The 240 volt mains is reduced to 40 Vac by the transformer and, depending on which supply is being built, rectified to either 25 or 50 Vdc. This voltage is only nominal as the actual voltage will vary between 29 volts (58 volts) on no-load to 21 volts (42 volts) at full load. The same filter capacitors are used in either case. They are connected in parallel for the 25 volt version (5000 μF) and in series for the 50 volt version (1250μF). In the 50 volt version the centre tap of the transformer is connected to the centre tap of the capacitors thus ensuring correct voltage sharing between the capacitors. This arrangement also provides a 25 volt supply for the regulator IC.

The voltage regulator is basically a series type where the impedance of the series transistor is controlled in such a way that the voltage across the load is maintained constant at the preset value. The transistor Q4 dissipates a lot of power especially at low output voltages and high current and is therefore mounted on the heatsink on the rear of the unit. Transistor Q3 adds current gain to Q4, the combination acting as a high-power, high-gain, PNP transistor.

The 25 volts is reduced to 12 volts by the integrated-circuit regulator IC1. This voltage is used as the supply voltage for the CA3130 ICs and is further reduced to 5.1 volts by zener diode ZD1 for use as the reference voltage. The voltage regulation is performed by IC3 which compares the voltage as selected by RV3 (0 to 5.1 volts) with the output voltage as divided By R12 and R13. The divider gives a division of 4.2 (0 to 21 volts) or eight (0 to 40 volts). However at the high end the available voltage is limited by the fact that the regulator loses control at high current as the voltage across the filter capacitor approaches the output voltage and some 100 Hz ripple will also be present. The output of IC3 controls transistor Q2 which in turn controls the output transistor such that the output voltage remains constant regardless of line and load variations. The 5.1 volt reference is supplied to the emitter of Q2 via Q1. This transistor is in effect a buffer stage to prevent the 5.1 volt line from being loaded.

Current control is performed by IC2 which compares the voltage selected by RV1 (0 to 0.55 volts) with the voltage generated across R5 by the load current. If say 0.25 volts is set on RV1 and the current drawn from the supply is low, the output of IC2 will be near 12 volts.

This causes LED 2 to be illuminated as the emitter of Q1 is at 5.7 volts. This LED therefore indicates that the supply is operating in the voltage-regulator mode. If however the current drawn is increased such that the voltage across R5 is just above 0.25 volts (in our example) the output of IC2 will fall. When the output of IC2 falls below about 4 volts Q2 starts to turn off via LED 3 and D5.

The effect of this is to reduce the output voltage so that the voltage across R7 cannot rise further. When this happens the voltage comparator IC3 tries to correct for the condition and its output rises to 12 volts. IC2 then takes more current to compensate and this current causes LED 3 to light, indicating that the supply is operating in the current-limit mode.

To ensure accurate regulation the voltage sensing leads are taken to the output terminals separately from those carrying the load current.

The meter has a one milliamp movement and measures the output voltage (directly across the output terminals) or current (by measuring the voltage across R5) as selected by the front panel switch SW2.

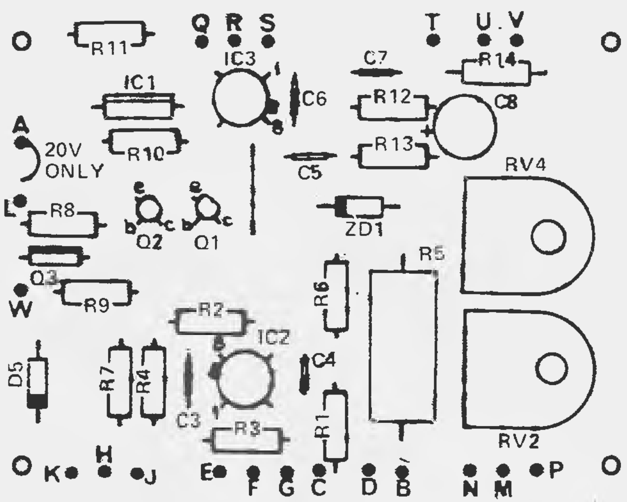
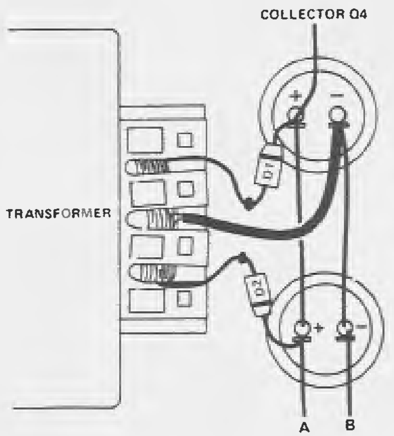


Fig. 3. Component overlay for the printed-circuit board assembly.



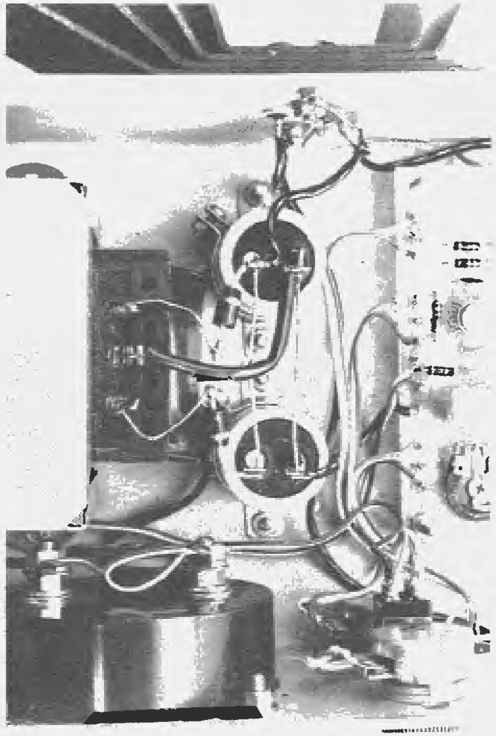
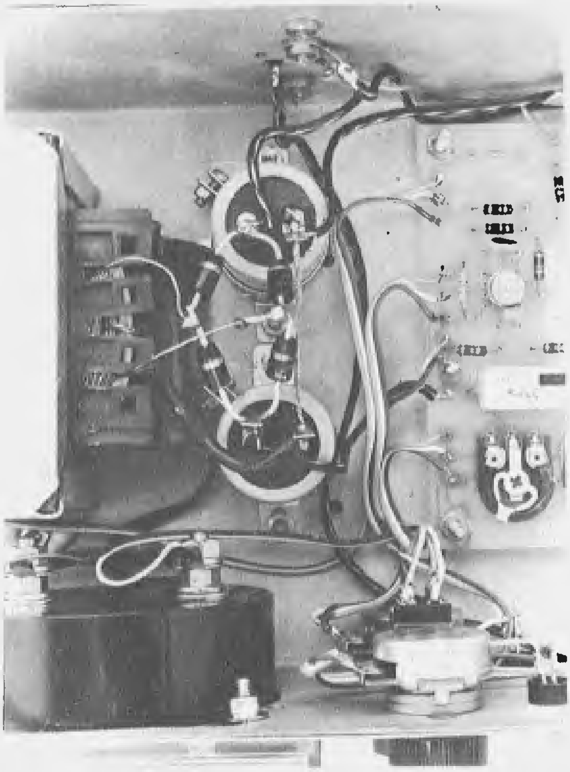


Fig. 4. How the supply is wired for the 20 volt 2.5 ampere version.

General purpose power supply



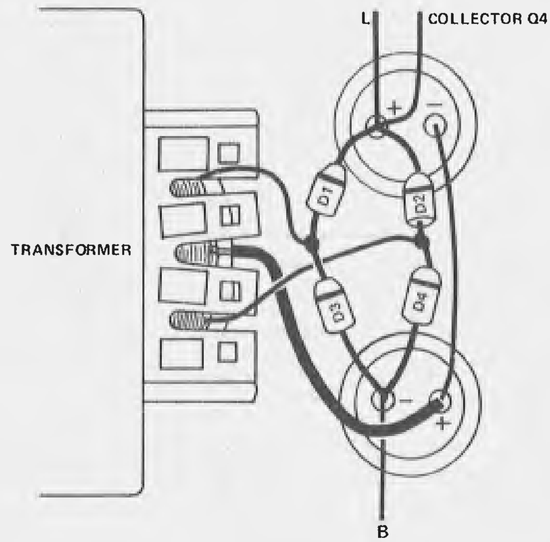


Fig. 5. How the supply is wired for the 40 volt 1.25 ampere version.

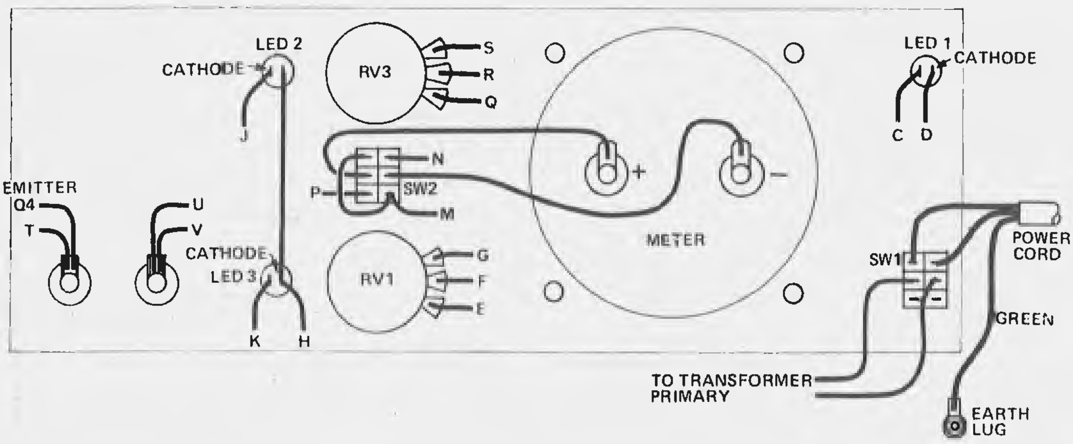


Fig. 6. Front panel wiring diagram.

rail we chose to use a CA3130 IC operational amplifier as the comparator. The CA3130 requires a single supply (maximum of 15 volts) and, initially, we used a resistor and 12 volt zener to derive a 12 volt supply. The reference voltage was then derived from this zener supply by another resistor and a 5 volt zener. It was felt that this would have given sufficient regulation for the reference voltage but in practice the output from the rectifier was found to vary from 21 to 29 volts and some of the ripple and voltage change that occurred across the 12 volt zener, as a consequence, was reflected into the 5 volt zener reference. For this reason the 12 volt zener was replaced by an IC regulator which cured the problem.

With all series regulators the series-output transistor by the nature of the design, must dissipate a lot of power especially at low output voltage and high current. For this reason an adequate heatsink is an essential part of the design. Commercial heatsinks are very expensive and sometimes difficult to mount. We therefore designed our own heatsink which was not only cheaper but worked better than the commercial version we had been considering — being easier to mount. However at full load the heatsink still runs hot as does the transformer, and under high-current low-voltage conditions the transistor may even be too hot to touch. This is quite normal as the transistor under these conditions is still operating within its specified temperature range.

With any highly regulated supply, stability can be a problem. For this reason in the voltage-regulation mode of operation, capacitors C5 and C7 are incorporated to reduce the loop gain at high frequencies and thus prevent the supply from oscillating. The value of C5 has been chosen for best compromise between stability and response time. If the value of C5 is too low the speed of response is greater — but there is a higher chance of instability. If too high

the response time is unduly increased.

In the current-limit mode the same function is performed by C4 and the same remarks apply as for the voltage case.

As the supply is capable of fairly high current output there is inevitably some voltage drop across the wiring to the output terminals. This is overcome by sensing the voltage at the output terminals via a separate pair of leads.

Whilst the supply was primarily designed for 20 volts at 2.5 amps it was suggested that the same supply could be used to supply 40 volts at 1.25 amps and that this would be of more value to some users. This may be done by changing the configuration of the rectifier and by changing a few components. Some thought was given to making the supply switchable but the extra complication and expense were such that it was not considered to be worthwhile. Thus you should simply decide which configuration suits your need and build the supply accordingly.

The maximum regulated voltage available is limited either by the input voltage to the regulator being too low (at over 18 volts and 2.5 amps) or by the ratio of R12/R13 and by the value of the reference voltage.

$$(\text{Output} = \frac{R12 + R13}{R13}\ V\text{ref})$$

Due to the tolerance of ZD1 the full 20 volts (or 40 volts) may not be obtainable. If this is found to be the case R12 should be increased to the next preferred value.

Single turn potentiometers have been specified for the voltage and current controls because they are inexpensive. However if precise setability of voltage or current limit is required ten-turn potentiometers should be used instead.

CONSTRUCTION

The recommended printed-circuit board layout should be used as construction is thereby greatly simplified. Printed-circuit board pins should also be used for the 20 wire connections to the board. These should be installed first. The rest of the components may now be assembled onto the board making sure that the polarities of diodes, transistors, ICs and electrolytics are correct. The BD140 (Q3) should be mounted such that the side with the metal surface faces towards IC1. A small heatsink should be bolted onto the transistor as shown in the photograph.

If the metalwork as described is used the following assembly order should be used.

a) Mate the front panel to the front of the chassis and secure them together by installing the meter.

b) Fit the output terminals, potentiometers and meter switch on to the front panel.

c) The cathodes of the LEDs (that we used) were marked by a notch in the body which could not be seen when the LEDs were mounted onto the front panel. If this is the case with yours, cut the cathode leads a little shorter to identify them and then mount the LEDs into position.

d) Solder lengths of wire (about 180 mm long) to the 240 volt terminals of the transformer, insulate the terminals with tape and then mount the transformer into position in the chassis.

f) Install the power cord and the cord retaining clip, wire the power switch,

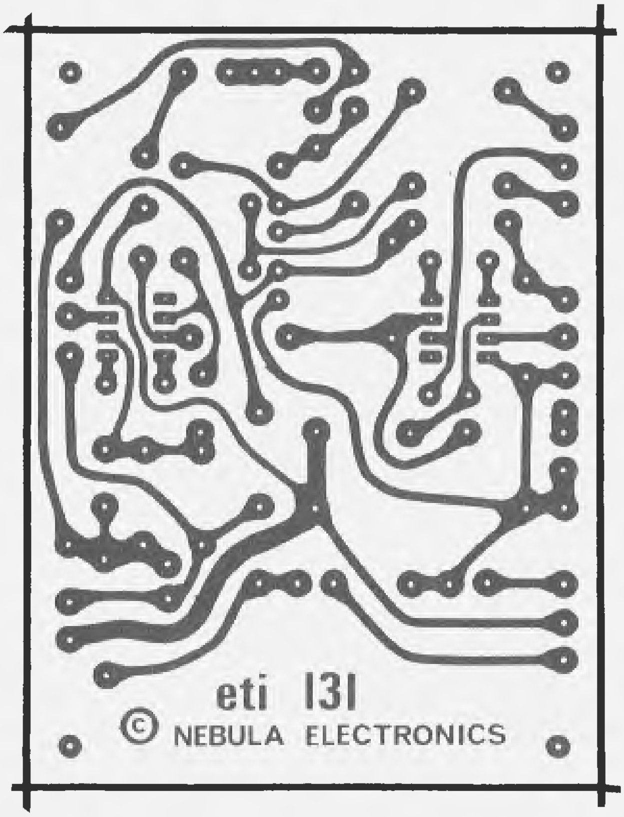


Fig. 7. Printed-circuit board layout for the power supply. Full size 100 x 75 mm.

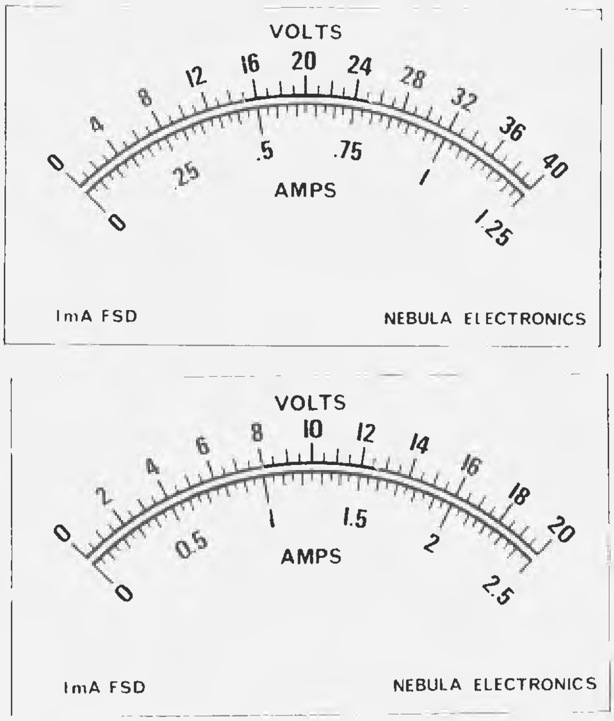


Fig. 8. Scales for the alternative meters for the unit shown full size.

General purpose power supply

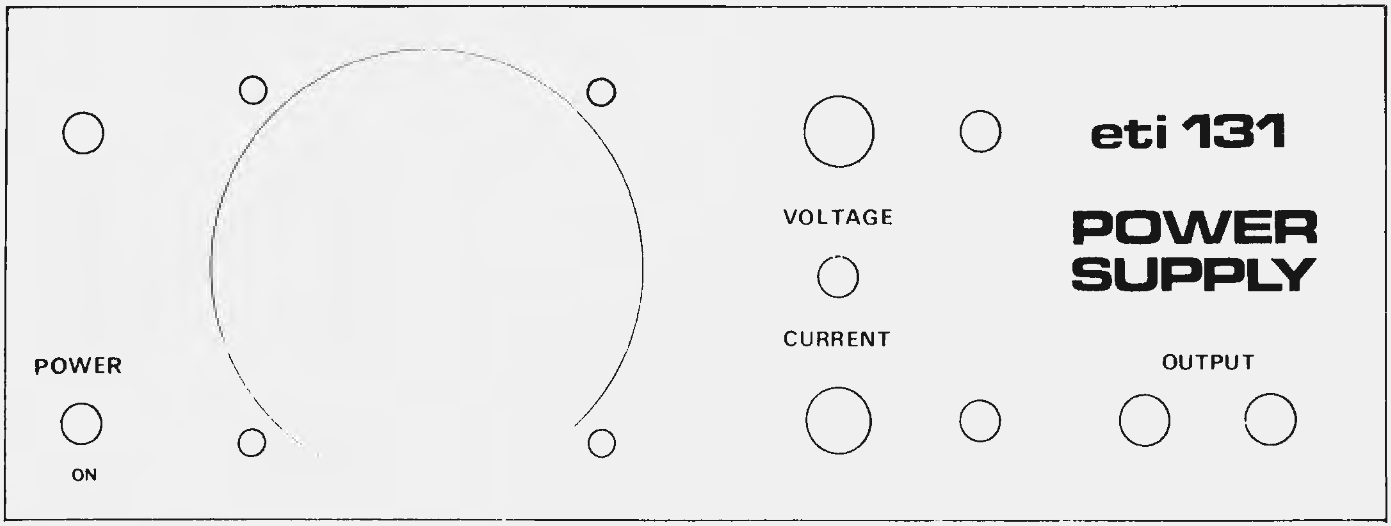


Fig. 9. Artwork for the front panel. Full size 224 x 82 mm.

insulate the terminals and then mount the switch onto the front panel.

g) Assemble the heatsink and screw it onto the rear of the chassis via two bolts – then mount the power transister using insulation washers and silicon grease.

h) Mount the assembled printed-circuit board to the chassis using 10 mm spacers.

i) Wire the transformer secondary, rectifier diodes and filter capacitors. The diode leads are stiff enough not to need any additional support.

j) The wiring between the board and the switches may now be made by connecting points with corresponding letters on the front panel diagram and component overlay diagrams.

The only setting up required is to calibrate the meter. Connect an accurate voltmeter to the output terminals and wind up the voltage control of the power supply until the external meter reads 15 volts (or 30 volts on the alternate arrangement). Switch the internal meter to read volts and adjust RV4 to obtain the same reading.

To set up the current reading first wind the supply voltage down to zero and connect an accurate ammeter across the output. Wind up the voltage control and observe that the current limit LED is on. Now adjust the current limit control so that the external meter indicates two amps (or one amp on the alternative unit). Now adjust RV2 so that the same reading is obtained on the internal meter when it is switched to the current position.

PARTS LIST – ETI 131A

Resistors

R1	–	1 k	½ W	5%
R2	–	1 k	"	"
R3	–	1 k5	"	"
R4	–	10 k	"	"
R5	–	0.22 ohm 5 W		
R6	–	10 k	½ W	5%
R7	–	1 k	"	"
R8	–	1 k	"	"
R9	–	1 k	"	"
R10	–	1 k	"	"
R11	–	47	"	"
R12	–	18 k	"	"
R13	–	5 k6	"	"
R14	–	15 k	"	"

Potentiometers

RV1	–	10 k lin rotary
RV2	–	1 k trim
RV3	–	10 k lin rotary
RV4	–	10 k trim

Capacitors

C1	–	2500 μF 35V electro
C2	–	2500 μF 35V electro
C3	–	68 pF ceramic
C4	–	150 pF "
C5	–	820 pF "
C6	–	68 pF "
C7	–	68 pF "
C8	–	47 μF 50V electro

Complete kits of components for this project can be obtained from Nebula Electronics Pty Ltd, 4th Floor, 15 Boundary St, Rushcutters Bay (telephone 33-5850).

Transistors

Q1	–	BC559
Q2	–	BC547
Q3	–	BD140
Q4	–	2N3055 (with insulation kit)

Diodes

D1,2	–	IN5404
D5	–	IN914

Other Semiconductors

ZD1	Zener Diode	5.1V 400 mW
LED 1,2	LED	5023 or similar
IC1	Integrated Circuit	LM341P-12
IC2,3	" "	CA3130

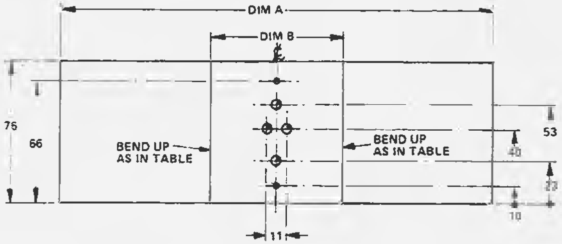
Miscellaneous

PC board ETI 131
Transformer 40V CT 2A A&R 5755
SW1,2 switch DPDT toggle
Meter 1 mA FSD scaled 0-20V, 0-2.5A
Chassis to Fig. 11
Cover to Fig. 13
Heatsink to Fig. 10
Front panel to Fig. 9
Two terminals
Power cord & clamp
Two knobs
Four 10 mm long spacers
20 PC board pins
Four rubber feet
nuts, bolts, washers etc.

PARTS LIST – ETI 131B

All parts for ETI 131A except

Change	R3	to	1 k8
	R5	to	0.47 ohm
	R12	to	39 k
	R14	to	33 k
	RV4	to	25 k



o 2 HOLES 3.2mm DIA.

4 HOLES 5mm DIA.

MATERIAL 1.6mm ALUM BLACK ANODISED

ALL DIMENSIONS IN MILLIMETRES.

	DIM.A	DIM. B	ANGLE
ITEM 1	110	40	75°
ITEM 2	130	50	60°
ITEM 3	170	60	45°
ITEM 4	230	70	30°

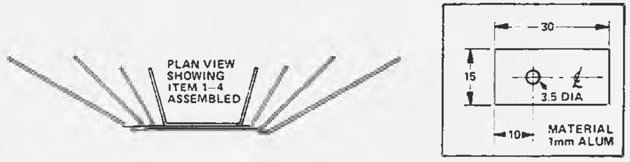


Fig. 10. Heatsink detail.

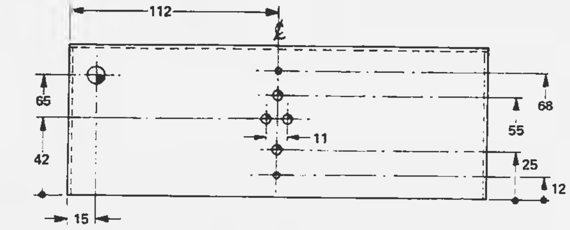
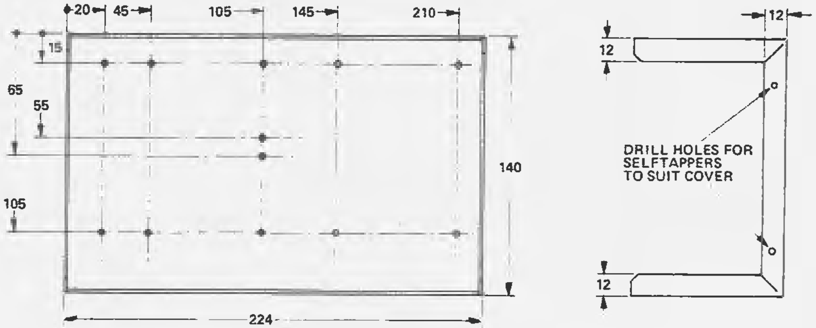


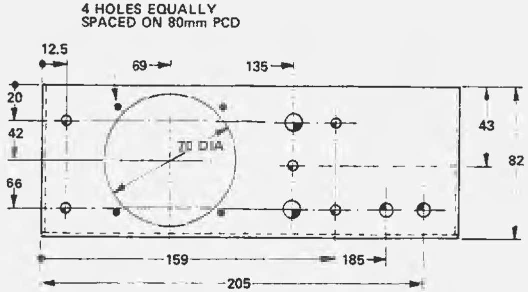
Fig. 11. Chassis metalwork.

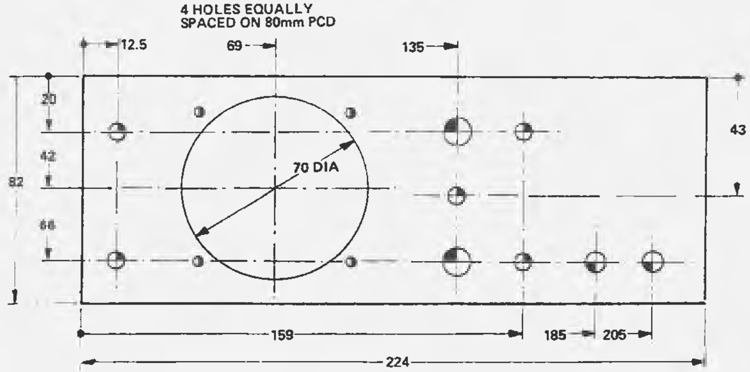


o 6 HOLES 3.2mm DIA
• 12 HOLES 4mm DIA
4 HOLES 5mm DIA
5 HOLES 6.4mm DIA
2 HOLES 8mm DIA
3 HOLES 10mm DIA

ALL DIMENSIONS IN MILLIMETRES

MATERIAL 1mm STEEL





4 HOLES 4mm DIA
5 HOLES 6.4mm DIA
2 HOLES 8mm DIA
2 HOLES 10mm DIA

ALL DIMENSIONS IN MILLIMETRES

MATERIAL SATIN ANODISED ALUMINIUM SILK SCREENED.

Fig. 12. Front panel drilling.

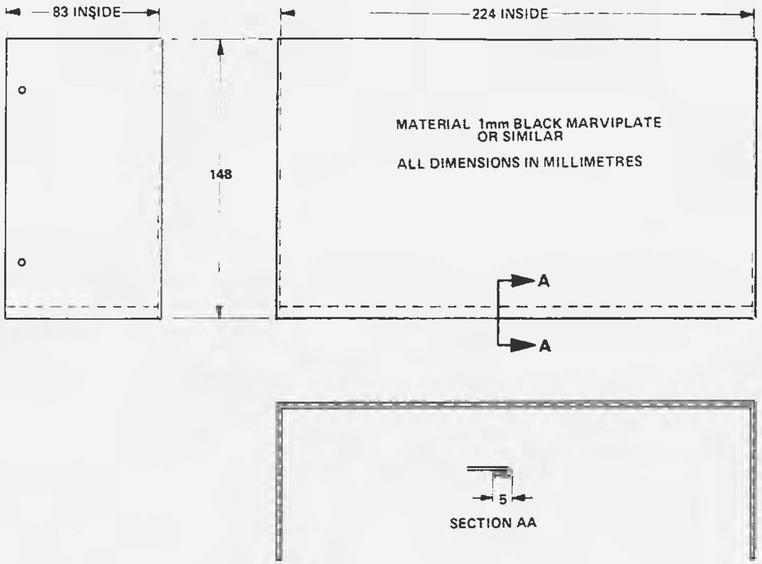
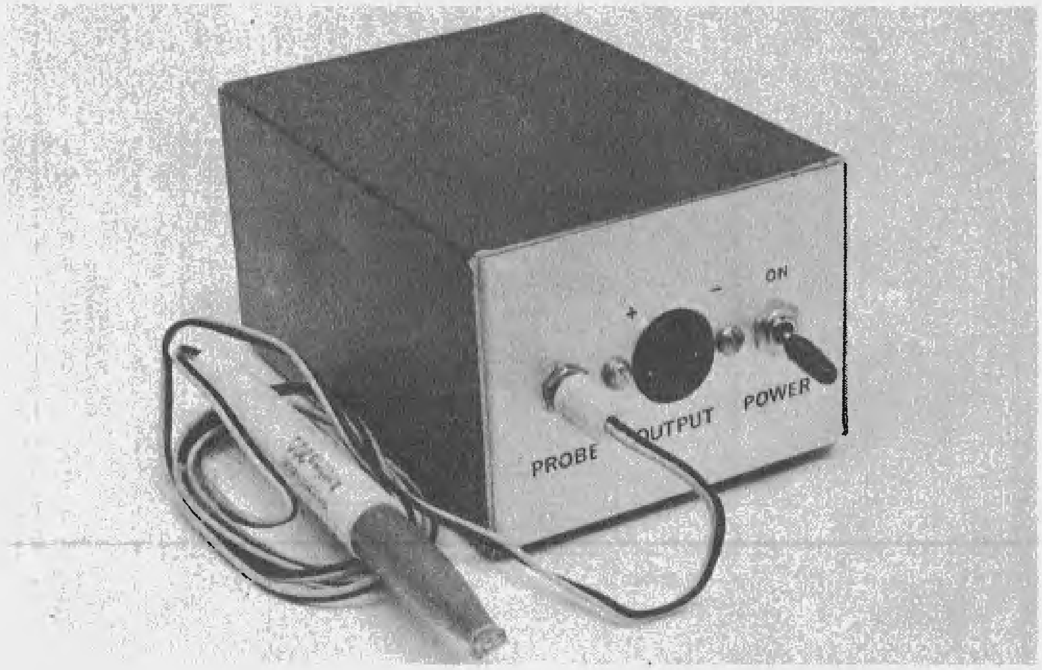


Fig. 13. Detail of metal cover.

TEMPERATURE METER

PROJECT 130



Converter connects to any analogue or digital meter.

OUR original design concept for this unit was as a complete instrument based on our ETI 533 digital display using a forward biased diode as the sensor — this generating a temperature-proportional voltage which in turn is supplied to a voltage-to-frequency converter. We planned to use a timebase to generate the necessary strobe and reset pulses. However the cost and complexity of this arrangement was such that we decided against it.

What finally emerged was a simple temperature-to-voltage converter which can be used in front of *any* analogue or digital meter. The converter provides an output of 10 mV/degree which can be either Celsius or Fahrenheit depending on calibration. If a dedicated digital readout is required we suggest that you incorporate the converter with our ETI 118 digital voltmeter.

CONSTRUCTION

Whilst a printed-circuit board is by no means essential, using one certainly makes construction easier and improves the appearance. The potentiometers as shown in our prototype are single turn presets which are quite adequate if an analogue meter is to be used for the readout. However if a digital meter is to be used the extra accuracy of the readout would warrant ten-turn presets being used for RV1 and RV2, as setting accuracy is considerably improved.

The converter quite readily fits into a small aluminium mini-box. Two nine volt batteries are used to power the unit and battery drain is low enough to ensure a life of many months.

A 3.5 mm jack is used to connect the sensor to the unit and the output to the meter is provided via an inexpensive two-pin speaker socket.

The probe is constructed by mounting the sensor-diode into the tip of a ball-point pen casing, or similar. The method may best be understood by reference to the drawing.

CALIBRATION

To calibrate the instrument, two accurately known temperatures are required. One may be water or oil at room temperature (ice water should not be used as there the temperature may vary several degrees between different points in the solution). The high temperature is best obtained by heating oil or water and allowing it to stabilise at around 80°C. A second smaller heat conductive container filled with water is then immersed in the larger container. This simple procedure prevents errors due to circulating currents in the larger volume of water. An accurate mercury-in-glass thermometer should be used to measure temperatures during the calibration procedure as detailed below.

SPECIFICATION

RANGE	0 to 100°C 32 to 212°F
OUTPUT	10 mV/degree
ACCURACY	± 1°
RESPONSE TIME	3 seconds

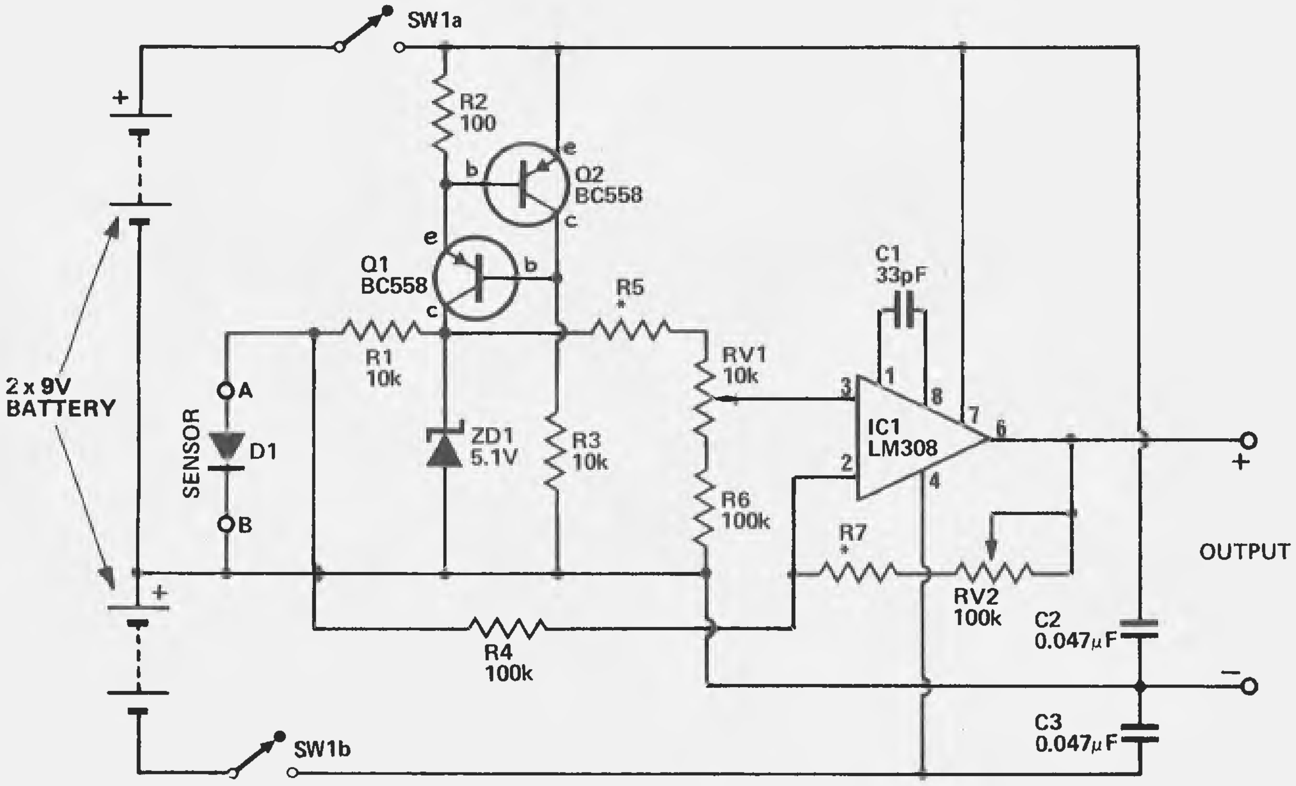


Fig. 1. Circuit diagram of the temperature meter.

NOTE
FOR DEGREES F
R5 = 750k
R7 = 820k
FOR DEGREES C
R5 = 910k
R7 = 470k

HOW IT WORKS – ETI 130.

A forward biased diode has a temperature coefficient of about −2 mV/°C. That is the normal voltage across a silicon diode of nominally 0.6 volts will decrease by two millivolts for every degree C increase in temperature. This change with temperature is sufficiently linear over the range of 0 to 100°C to use it as a temperature sensor.

What the ETI 130 circuit does is to amplify this voltage and to provide offset compensation for the normal 0.6 volt drop across the diode.

Transistors Q1 and Q2 provide a constant-current source of about 5 mA into the zener diode ZD1 such that a very stable five volt reference is obtained which is independent of the battery supply voltage. (V supply greater than 6 V.) The forward bias current through the sensor diode is about 0.5 mA as provided by R1. This current is low enough to prevent errors due to self heating of the sensor diode.

The voltage across the sensor diode is amplified by IC1 (a very high input-impedance operational amplifier) whose gain is fixed at the ratio of (R7 + RV2)/R4. The necessary offset is provided by RV1 which is adjusted to cancel the normal 0.6 volt drop across the diode. By selecting the correct values for R5 and R7 as shown on the circuit diagram the indication of temperature in degrees C or F may be obtained.

1. Place the sensor and thermometer into the cool solution, allow a little time for stabilisation, and then measure the voltage from the converter and the temperature. Record these two readings.

2. Place the sensor and thermometer into the hot solution and measure the voltage and temperature as before. The voltage change between the first and second readings should be equal to the temperature change times 10 millivolts.

3. If the voltage versus temperature is not as specified in step 2 adjust RV2 and repeat steps 1 and 2 until it is. Note that varying RV2 changes the voltage at both the hot and the cold positions. It is the correct slope, or rate of change that we are after at the moment.

4. When the correct rate of change has been set as above place the sensor and thermometer into the cool solution and adjust RV1 to obtain a reading of 10 mV per degree. That is if the solution is at 25° C adjust RV1 to obtain a reading of 0.25 V.

Due to the spread of diode characteristics from one device to another the necessarily small adjustment range of RV1 and RV2 may not allow all diodes to be calibrated with the resistor values specified. If this is found to be the case it may be necessary to change the value of R5, R6 or R7.

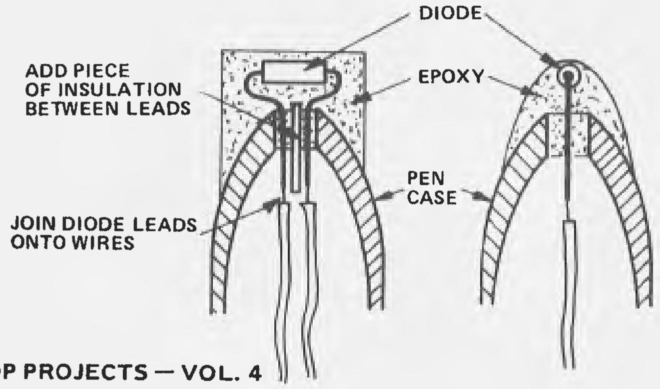


Fig. 2. This diagram shows how the sensor is mounted into a ball-point pen casing or similar.

PARTS LIST

R1,3	Resistor	10k	½W 5%
R2	"	100	½W 5%
R4,6	"	100k	½W 5%
R5,7	"	See Fig. 1 and test.	
RV1	Potentiometer	10k * trim type	
RV2	"	100k * "	"
*for digital readout a multiturn trim potentiometer is recommended.			
C1	Capacitor	33pF ceramic	
C2,3	"	0.047μF polyester	
D1	Diode	1N914	
ZD2	Zener Diode	BZX79C5V1	
Q1,2	Transistor	BC558, BC178	
IC1	Integrated Circuit	LM308	

Metal box
Two 9v batteries
Two pole toggle switch
PC board ETI 130
3.5mm plug and socket
Two pin plug and socket for output

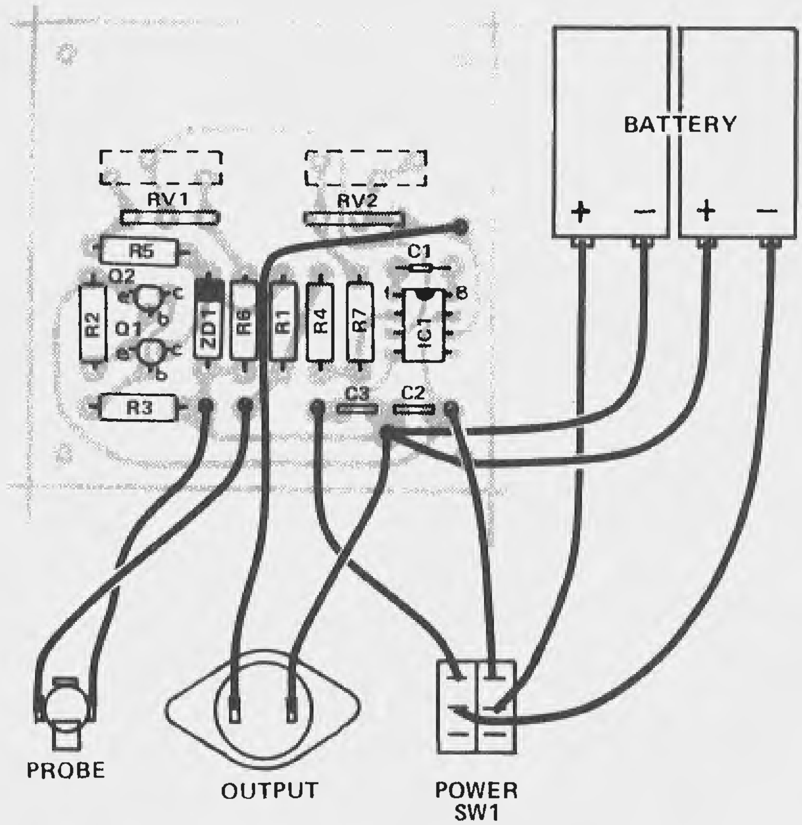


Fig. 3. Component overlay and interconnection diagram.

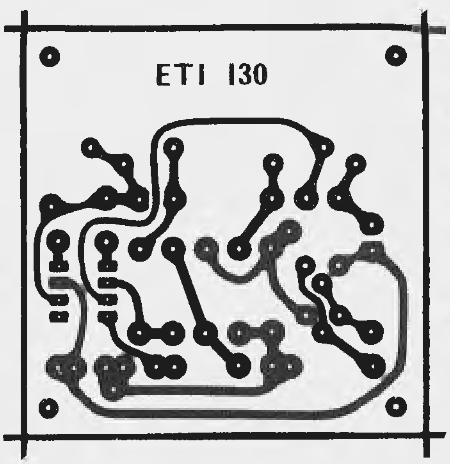
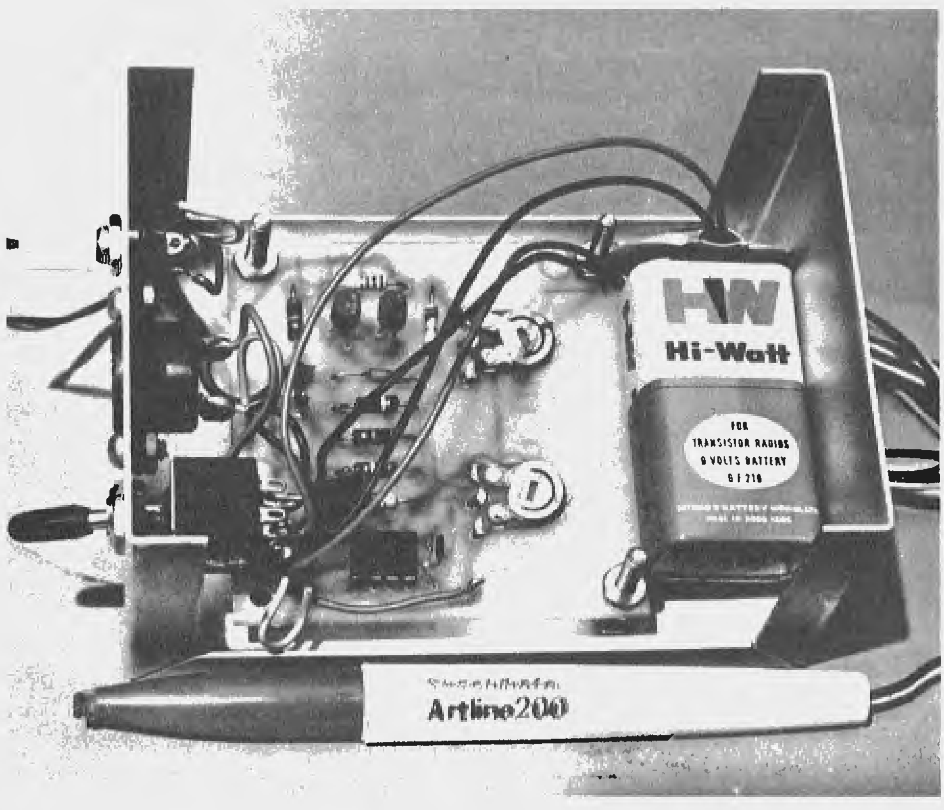


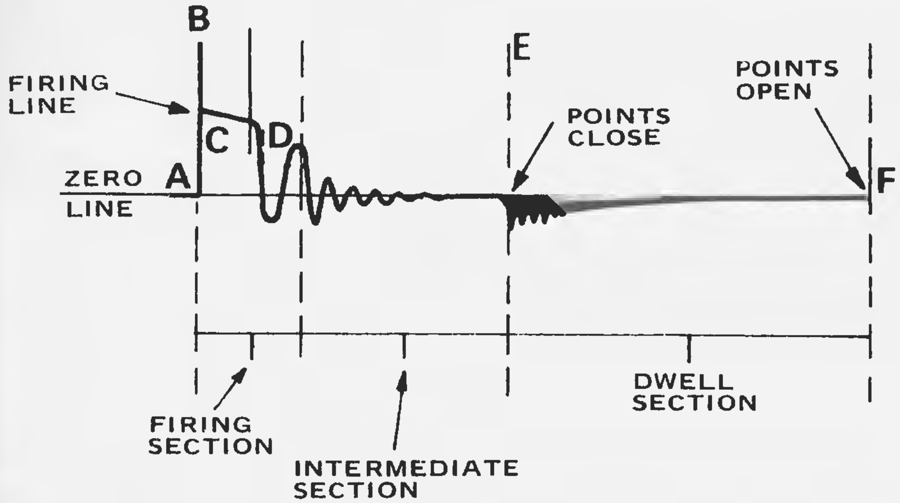
Fig. 4. Printed circuit pattern. Full size 63 x 63 mm.



Internal view of the completed temperature converter. Note also the probe at front.

'Scope test your car

How to use your 'scope to check out a car's carburetion and ignition systems.



AUTOMOBILE ENGINE TUNING IS A grossly misused and misunderstood operation. To many it implies some esoteric knowledge or ability – of listening to an engine and somehow deducing that the ignition must be advanced – or the mixture strength richened a bit on the front carburettor.

In reality it consists almost entirely of ensuring that ignition and carburetion is adjusted to the vehicle manufacturer's specifications.

No more – no less.

But to do this it is virtually essential to use at least some basic instrumentation; a dwell meter, a tachometer, a good exhaust gas analyser – and preferably an ignition analyser.

Many car enthusiasts have at least a tacho/dwell meter – but few have access to an ignition analyser for such devices are costly indeed. Nevertheless if a few limitations are accepted virtually *any* standard oscilloscope can be used as an ignition analyser simply by making a couple of very simple capacitive probes – which can be as simple as clothes pegs and a few square inches of aluminium foil.

An ignition analyser displays waveforms from the primary or secondary side of the vehicle's ignition system. Surprisingly perhaps, this waveform provides information not only about the ignition system in general but also about carburetion, and a number of mechanical conditions.

The analyser can do this because the voltage required to fire a petrol/air mixture in an engine is affected by many different variables including air/fuel ratio, cylinder compression, ignition timing, ignition polarity, spark plug gap and condition etc, etc.

THE SECONDARY WAVEFORM

The simple waveform shown at the beginning of this article is a typical secondary waveform that is derived from the secondary (or high voltage) side of the ignition system. This waveform is the one most commonly used since phenomena occuring in the primary side of the system will be reflected through the coil windings and appear in the secondary pattern.

Point A: is the instant at which the contact points open thus causing the magnetic field to collapse through the coil's primary winding. A very high voltage is thus generated in the secondary winding and this continues to rise – until a spark jumps across the distributor rotor gap and the spark plug gap (point B). The voltage at which this occurs is known as the 'ionization' or the 'firing' voltage and may be anywhere between 5 kV and 15 kV depending on the factors outlined above.

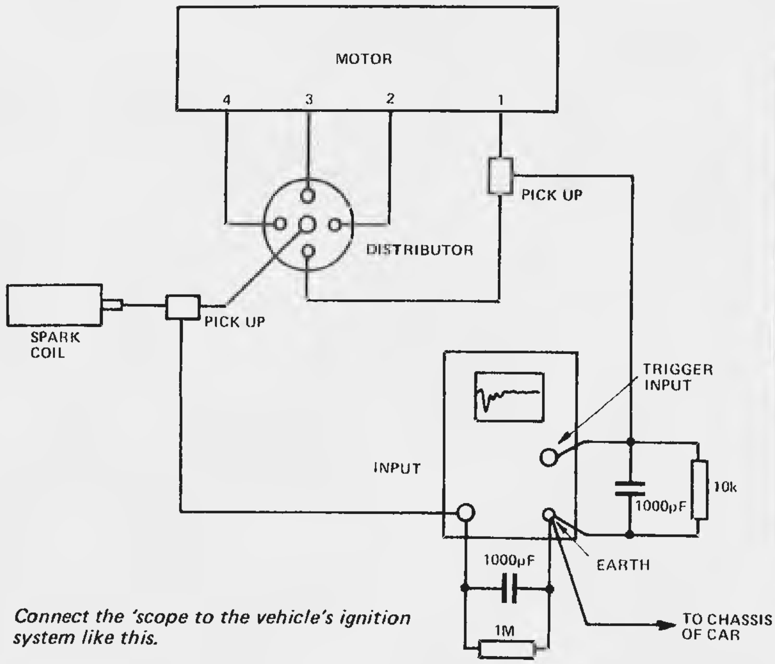
Points C–D: after a very short time the voltage drops substantially but the arc is maintained (point C). The subsequent section from point C to point D is known as the spark line and when viewed on a 'scope the amount by which this line slopes away from the horizontal is directly related to resistance in the plug and coil ht leads (ignition suppression). A slope of 30° or so is OK – if it's more than that then it's worth checking lead resistance with an ohmeter. The total resistance between the centre terminal of the coil and the centre electrode of the plug should not exceed about 20 k assuming the rotor gap is shorted out of course! Actual resistance is not critical but anything more than 30 k may cause problems. Resistance over 50 k almost certainly will.

Point D: the section immediately following the end of the spark line (point D) should be a series of diminishing oscillations. These should appear as our illustration. If there are no oscillations – or just one or two – then it's a safe bet that there's a shorted turn in the coil. It may not have broken down completely yet but it's a safe bet it shortly will. (See also below).

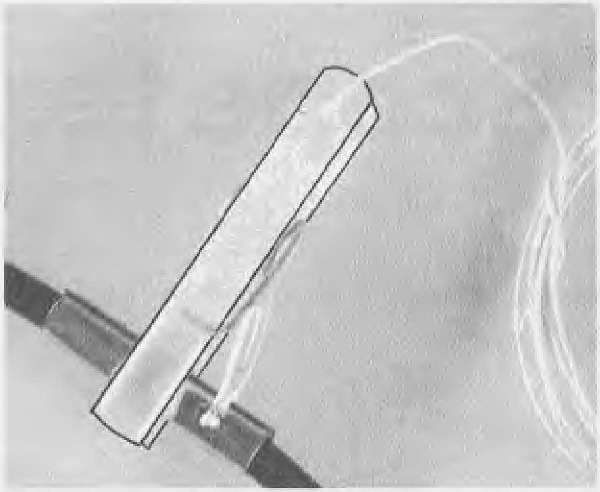
Point E: is where the contact breaker points close. It is essential that there is a gap between the last oscillation of the preceding section and point E for otherwise the diminishing coil energy will be fed into the now closed points thus preventing the coil re-building its magnetic field for the next cycle of ignition.

A great deal may be learnt by studying point E carefully, point misalignment, point bounce, burnt points etc may be spotted at this part of the waveform. The correct waveform at point E should be a short downward line followed by six or so diminishing oscillations.

Point F: magnetic energy will now build up in the coil until Point F. This is in effect the same point as our previous point A but in the next firing sequence. The section from points E to F is



Connect the 'scope to the vehicle's ignition system like this.



A simple pick-off can be made by glueing short lengths of split metal tube to a clothes peg.

CONNECTING THE 'SCOPE

A motor vehicle's ignition system produces output voltages varying from 3 kV to 20 kV or more. These high voltages must be reduced to a workable level before coupling into an oscilloscope.

The simplest way of doing this is via a resistive voltage divider — however a capacitive divider will work equally well (we are dealing with ac signals) and is simpler to connect.

We can make one of the capacitors by wrapping a piece of Alfoil — about 50 mm long — around the required lead and connecting this foil to the scope. A more professional approach is to glue a short length of split tube to a clothes-peg — as shown in the accompanying photograph. This will have a capacitance of about 1 pF — not much but ample for the massive signals we are sampling.

A second capacitor of about 1000 pF should be connected as shown. The capacitive divider thus formed divides the input signal by about 1000:1 thus reducing the input signal to a workable 3—20 volts. A 1 M resistor should be connected across the 1000 pF capacitor to provide a dc load.

The technique in use: Place the 1 pF capacitor over the main lead from the coil to the distributor and connect it to the 'Y' input of the scope.

If the scope has a trigger input this may be used to lock in the ignition signal. Just make up a second capacitive pick-up and place this around number 1 plug lead. Once again use a 1000 pF capacitor as a divider but bridge this capacitor with a 10 k resistor — not 1 M as previously.

Start the motor and adjust the 'Y' gain and timebase frequency to give four (or 6 or 8) complete firing sequences across the screen. The first complete pattern will be number 1 cylinder and the rest will follow in the engine firing order.

All waveforms may be superimposed by expanding the trace and triggering via the X input.

If the scope does not have a trigger input, synchronization is slightly harder to achieve. Number 1 cylinder may be identified simply by shorting out that cylinder momentarily.

When the scope is connected as described above, the ignition waveform will appear inverted relative to that seen on a commercially produced ignition analyser — and the waveforms shown in this article. It is surprisingly easy to adapt to an inverted picture, however if this is found to be a problem it can be remedied simply by coupling the signals into the scope via a simple 1:1 transformer. Details will vary from one scope to another but all that is basically needed is two coils of wire taped together. It may be necessary to reduce the 1000 pF capacitor/s to 470 pF. Just connect the secondary to give the correct picture.

If possible arrange to calibrate the scope's vertical axis so that the magnitude of the signals may be measured. This is best done simply by taking average indications from several vehicles and 'calibrating' by transferring data from the graphs in this article. The result may not be accurate but only a rough guide is required.

'Scope test your car

known as the dwell section and should occupy roughly the proportion of the total waveform as shown in our main drawing. Dwell is adjusted by varying the contact breaker gap and should be set using a dwell meter.

SPECIFIC INDICATIONS

Firing waveforms should be observed with the engine warm and running at about 1000 rpm — that is about 400 rpm higher than normal tickover speed.

Check each section of each firing sequence slowly and carefully. The various figures shown in this article indicate how specific faults will show up.

FIRING LINE

All firing lines should be of roughly equal height. If any plug is 10-15% or more higher than the rest, connect a jumper lead to earth and short out at the plug terminal. If the firing line now decreases the fault lies within that cylinder — either a faulty plug or

unusually weak mixture (probably caused by a leaking inlet manifold gasket). If the firing line does *not* decrease there is a partial open circuit in the associated plug lead or that lead is not making firm contact with the connector within the distributor cap.

If the firing lines are unequal on a multi-carburettored engine check to see if the lines which are higher correspond to those cylinders fed by one common carburettor. If so it is probable that the mixture from the carburettors is unbalanced. A further but less common fault that may be spotted this way is an eccentric distributor cap – the gap between rotor and distributor contacts being wider on one side than the other.

At some time during the check 'snap' the throttle wide open momentarily, meanwhile watching the firing lines. They should all rise by about the same amount. If one or more lines rise substantially higher than the others then there is an open circuit plug lead or resistor, a wide plug gap or badly deteriorated plug electrode.

One or more lines staying lower than normal indicates spark plug breakdown or insulation breakdown in the circuit concerned.

COIL OUTPUT AND INSULATION TEST

While the engine is running disconnect a plug lead and observe the firing pattern for that cylinder. The firing line should rise to about two to three times its previous level (to about 20 kV) and should extend below the base line by about half the upward distance.

If the firing line is short or intermittent – or if the lower section does not appear – then there is an insulation breakdown in the distributor cap, plug leads, rotor or coil.

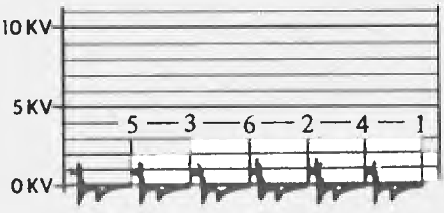
COIL AND CAPACITOR

A series of diminishing oscillations should be observed at point D in the waveform. If these do not appear, or are truncated, there is either a shorted or crossed turn in the coil – or the capacitor is breaking down.

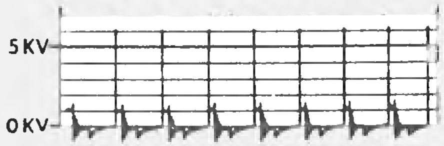
BREAKER POINTS

Point E on the main waveform. The drawings accompanying this article show various fault indications. Note however that faulty point action may also show up at the point opening position (A). Check breaker point action with the engine running at all speeds. Weak or incorrect breaker springs will cause the points to bounce – and this is readily seen on the scope pattern.

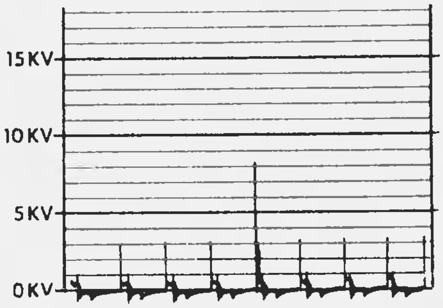
FIRING LINE INDICATIONS



Normal pattern:
Note that the firing line for cyl. 1 appears at the extreme end of the trace. The remaining cylinders then appear in engine firing sequence.



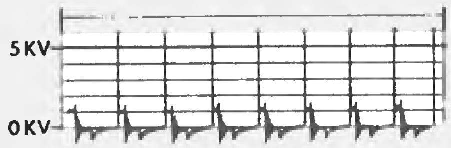
Firing lines even but high:
Excess plug gaps, rotor gap, break in coil ht lead, mixture too lean ignition retarded.



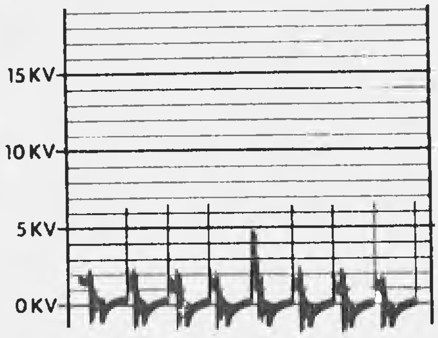
Firing line high on ONE cylinder:
Break in plug lead, broken electrode in spark plug. To test short plug – if line drops, problem is within cylinder.

Firing lines uneven:
Break in plug leads, worn plugs, burnt distributor cap contacts, uneven air/fuel mixture.

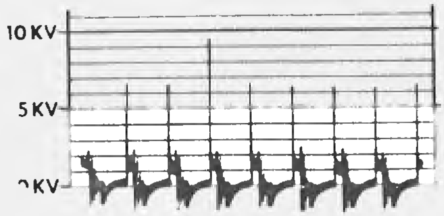
SNAP THROTTLE INDICATIONS



All lines should rise but remain even.

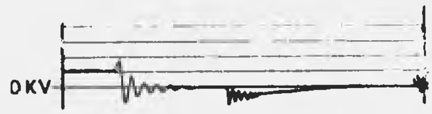


One line breaks up. Insulation break down – probably spark plug fouling. Extreme cases will show similar signal under normal steady running.

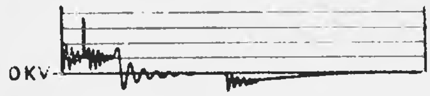


One line rises above rest. Wide plug gap, partial break in suppression resistor, plug lead etc.

CONTACT POINT INDICATIONS

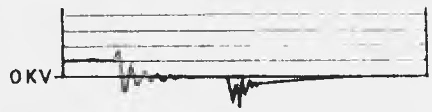


Unusual point opening signal (note hash extreme right of picture) burnt or arcing points.



Spike on spark line. Point arcing caused by faulty capacitor.

Points bouncing probably caused by weak closing spring.



Points misaligned – or dirty.

COIL

With very few exceptions – notably on some Citroens – the high voltage side of a vehicle's ignition system is designed to have positive earth – *regardless of overall vehicle battery polarity.*

The reason for this is that electrons are emitted more readily from a hot surface than a cold one so as a spark plug centre electrode always runs hundreds of degrees hotter than the side electrode the ignition system is devised so that a negative potential is applied to the centre electrode.

If this polarity is reversed, the plug will require an extra 5 kV or more to fire it – and that voltage may not be available from the coil under heavy load – or when running at light throttle at high speed (remember a weak mixture needs a higher voltage to ignite it than a rich one).

If you are checking polarity on a specialist ignition analyser then the polarity is correct if the pattern is as shown in the illustrations in this article. If you are checking it with a standard scope (with no inverting device) then the pattern should be upside down if polarity is correct. (See inset for full explanation).

Polarity is corrected simply by reversing the coil terminals. (Incorrect polarity is usually caused by a mechanic replacing a coil intended for a negative earth vehicle with a coil meant for a positive earth vehicle – or vice-versa. It may also, but less probably, be caused by an incorrectly manufactured coil, or less likely, by the vehicle's polarity being accidentally reversed by the battery being connected the wrong way round).

MIXTURE STRENGTH

This section is intended for the lucky man who has access to an exhaust gas analyser and tachometer as well as a scope.

If cylinder compression pressures are identical, plugs in good order and evenly gapped, and plug leads and distributor in good order – then any significant difference in firing line heights will almost certainly be caused by differing mixture strength from one cylinder to another.

The voltage required to fire a rich mixture is substantially less than for a weak mixture: for instance a 12:1 ratio may need 3 to 4 kV – whilst a 15:1 ratio may need 7 to 9 kV (typically). Thus even quite small differences in mixture strengths will be reflected quite dramatically in firing line height.

The only accurate way to adjust mixture strength is as follows:

Connect a tachometer to the engine and adjust slow running to 1000 rpm. *Without looking at the gas analyser* adjust mixture strengths so as to produce the highest tickover speed whilst maintaining the firing lines at an even height. If necessary reduce the tickover speed to keep it around 1000 rpm. Finally richen the mixture a shade until tickover speed drops by about 50 rpm.

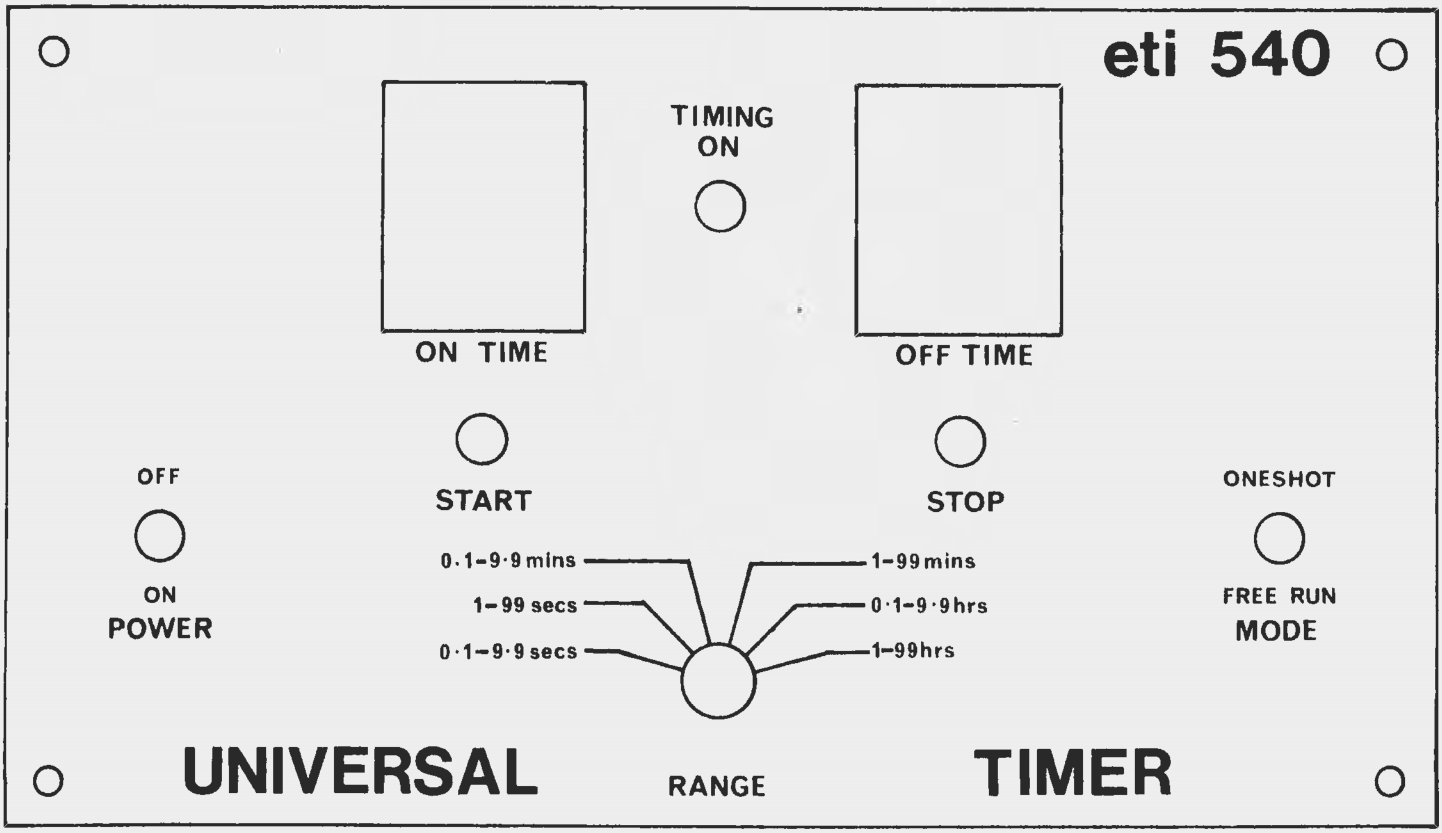
Then *and only then* – look at the gas analyser. You should now have a reading somewhere between 14:1 and 15:1. If you haven't then there's something wrong with the carburetion system – an air leak in the induction manifold: incorrect float chamber level: blocked slow running jet or *something.*

Never ever tune an engine by using a gas analyser alone – or in any other sequence than that spelled out above. If you do it's a certainty that sooner or later you're going to start with one fault and end up with two or more. ●

Universal timer

(Continued from page 70)

Fig. 5. Front panel artwork. Full size 190 x 109 mm.



Project 541

Train controller

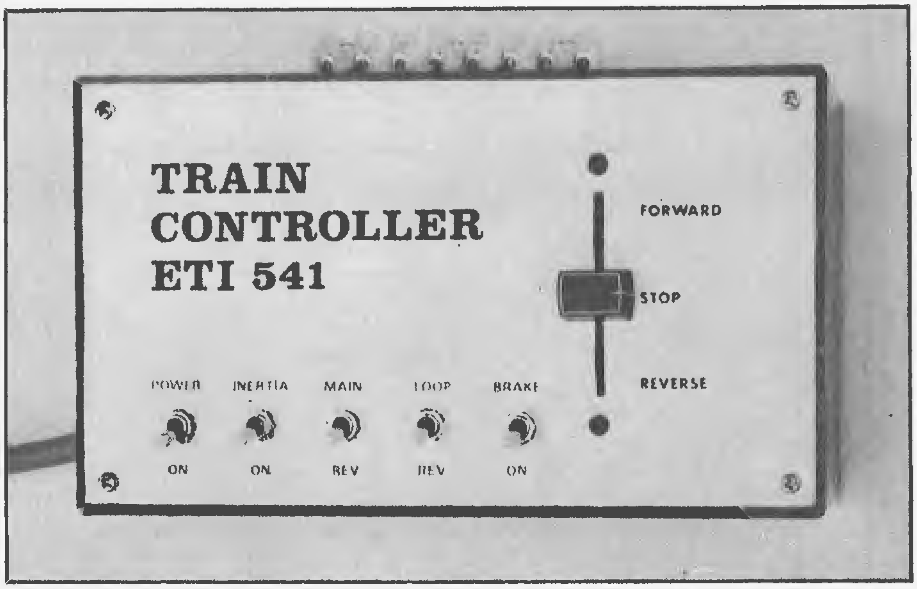
A simple project offering auto-reverse, inertia, emergency brake and loop track facilities.

MODEL TRAINS HAVE ALWAYS BEEN popular with both lads and dads — with dads perhaps coming first. Many a boy has complained "Daddy won't give me a turn". It seems there is some inexplicable attraction in playing trains which never dims with the passing years. A couple of our friends have recently decided to buy train sets — for the kids (they say). Our model train controller project was designed to give them many features that are not found in commercially available controllers (for roughly the same cost). Most commercial devices cost around $30 and consist of a transformer followed by a selenium rectifier, a high power rheostat and an automotive globe. Such controllers have numerous operating disadvantages mainly due to their very poor voltage regulation.

Our controller It may look a little complex but in fact it is very simple to build and quite inexpensive. If the full capability is used the features of the controller are:

- Forward or reverse control by a single slide potentiometer (centre for stop)
- Separate reversing switch for the main track
- Short-circuit proof
- Regulator-type control circuitry
- Emergency brake (which stops the train instantly regardless of the position of other controls
- Simulated inertia (gives more realistic starts and stops)
- The facility to operate with track loops

Loop operation Although not possible with simple controllers, loop operation adds much operating fun and realism to any model railroad and the feature is well worth including. A typical loop is shown in Fig. 1. and the operational problems of such a loop are as follows:



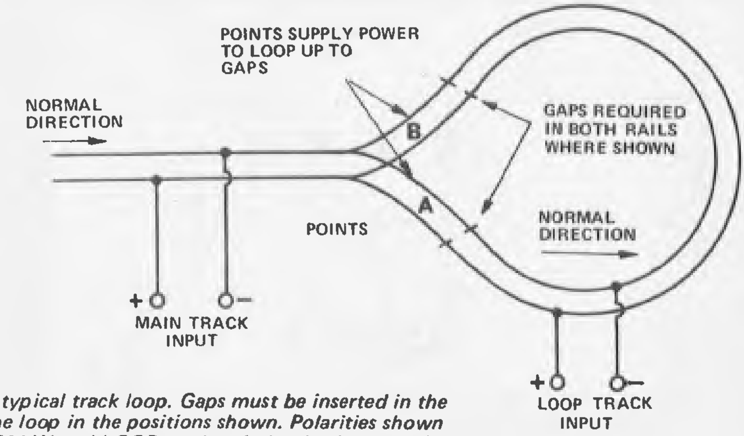


Fig. 1. A typical track loop. Gaps must be inserted in the rails of the loop in the positions shown. Polarities shown are with MAIN and LOOP track switches in the normal position.

If a train is approaching the loop and the 'main' and 'loop' switches are both set at normal, the polarity of the voltages to the track will be as shown. If the points are set so that the train enters the loop towards 'A' it will continue normally around the loop. If the points are now set to 'B' so that the train may

(Continued on page 97)

Train controller

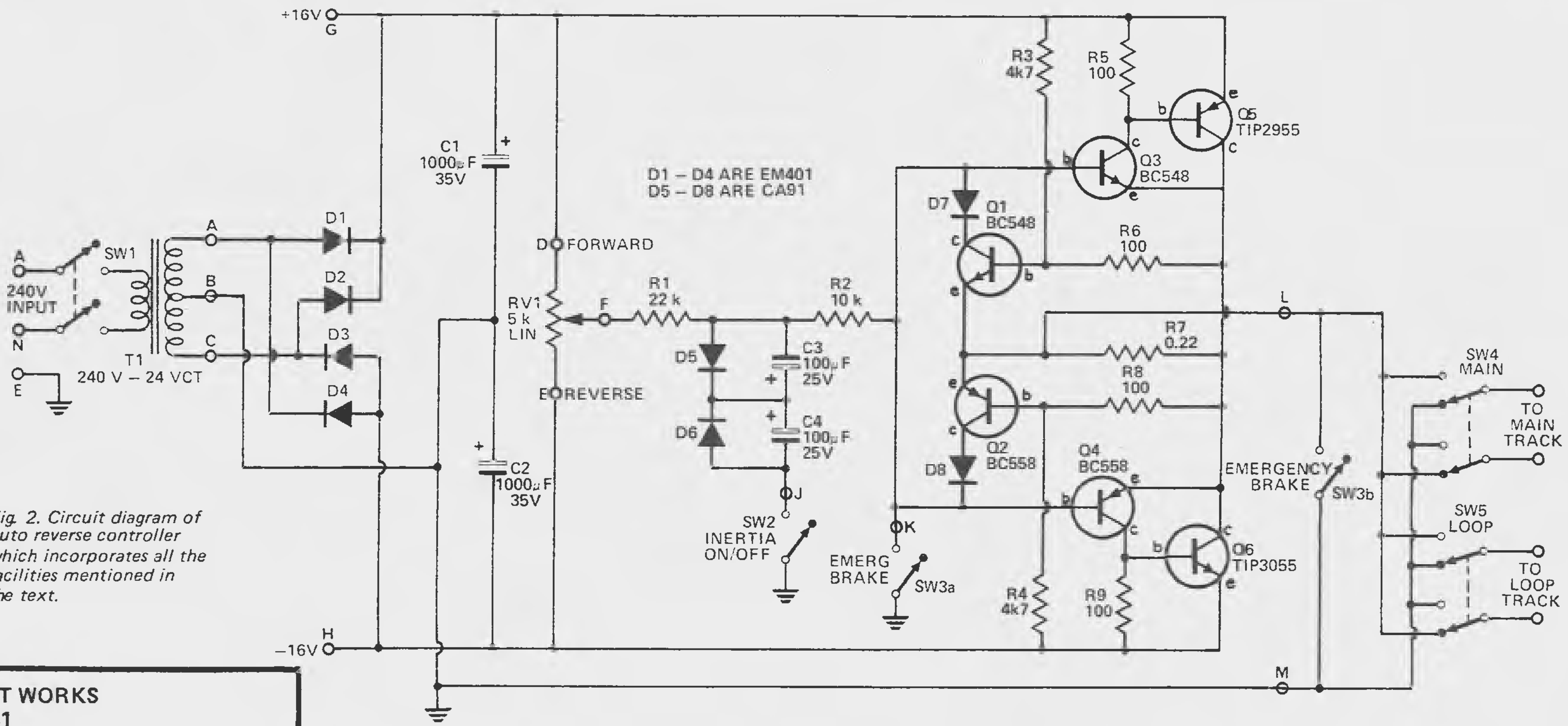
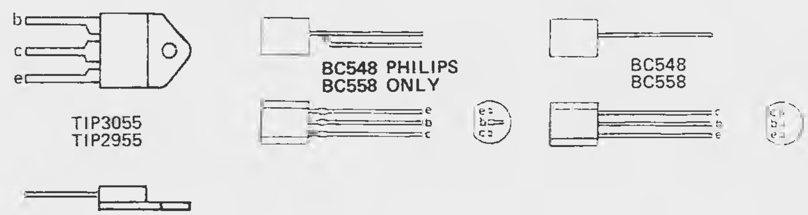


Fig. 2. Circuit diagram of auto reverse controller which incorporates all the facilities mentioned in the text.



HOW IT WORKS
ETI 541

TRANSFORMER T1 reduces the 240 volt mains to a supply of 24 volts (centre tapped) which is then rectified by D1 to D4 to provide supplies of +16 and −16 volts dc. The speed control potentiometer is connected between these supplies so that its wiper may select any potential between plus and minus 16 volts, depending on setting.

The output of the potentiometer must be well buffered before it can supply enough power to run a train. This is achieved by transistors Q3 and Q5, for the forward direction (that is for output voltages between zero and +15 volts), and by Q4 and Q6, for the reverse direction (that is for output voltages between zero and −15 volts). The output voltage at the collectors of Q5 and Q6 will be about 0.6 volts closer to zero than the voltage at point 'K' (providing the voltage at point 'K' is more than 0.6 volts away from zero). This means that the control

PARTS LIST
AUTOMATIC-REVERSE CONTROLLER

Resistors			
R1	22 k	½ W	5%
R2	10 k	"	"
R3,4	4 k7	"	"
R5,6	100 ohm	"	"
R7	0.22 ohm	5 W	"
R8,9	100 ohm	½ W	"
RV1	5 k lin 45 mm slide potentiometer		

potentiometer will have a small dead band in the centre of its travel where the output voltage remains at zero. This is an advantage because it is frequently necessary to set the controller for exact zero output.

To protect the transistors from damage in the event of an overload or a short circuit, transistors Q1 and Q2 are used to monitor the output current (by measuring the voltage across R7) and the voltage across the output transistors. By this method the power dissipation in the output transistors is controlled such than when driving into a short circuit only about one ampere is available. Yet when set to about 12 volts, about two amps is available to drive normal loads. The diodes D7 and D8 are included to protect the transistors Q1 and Q2 against reverse bias which can occur under certain conditions.

To add the 'inertia' facility or 'momentum', as it is sometimes called the control voltage from RV1 is filtered by C3 and C4. This means that if the potentiometer is suddenly moved from stop to full forward (for example) the voltage applied to the transistor buffer rises only slowly. The train accelerates at a realistic rate without wheel spin. A similar action takes place when the train is stopped. If the controller is moved from full forward to full reverse the train will slow down and stop for a short time and then start off and increase speed in the reverse direction. The diodes D5 and D6 allow normal electrolytics to be used in this position.

If inertia is being used and an emergency situation occurs, eg train moving into a siding that it should not be entering, the brake facility may be used to short the track (SW3b) and also the input to the buffer stage (SW3a). The brake over-rides the speed control and by its use the train will be stopped in a much shorter distance than it would if the power were simply switched off.

When loops in the track system are used, as described in the introduction, a separate reversing switch is used to control the polarity in the loop with respect to the main line so that the train may go into and come out off the loop without any change in speed. The two controller outputs required for this mode of operation must each be reversible and this is performed by SW4 and SW5.

If a second controller is required for another train in the system then it may be built without the power supply. The second controller may be powered by linking the +16, 0 and −16 volt lines between the two controllers.

Capacitors

C1,2	1000 μF 35 V pc mounting electro	
C3,4	100 μF 25 V pc mounting electro	

Transistors

Q1, 3	BC548
Q2, 4	BC558
Q5	TIP 2955 *
Q6	TIP 3055 *

* with insulation kit

Diodes

D1-D4	EM401 or similar
D5-D8	OA91 or similar

Miscellaneous

PC board ETI 541
Transformer PL24/20 VA or similar
SW1 toggleswitch DPDT 240 V rated
SW2 toggle switch SPDT
SW3-SW5 toggle switch DPDT
Plastic box 196x113x60 mm
12 Pc board pins
3 core flex, plug and clamp
Heatsink/support to Fig. 8.
8-way connector strip
2-way connector strip
2 6BA c/s screws & nuts 10 mm long
Front panel (Scotchcal)

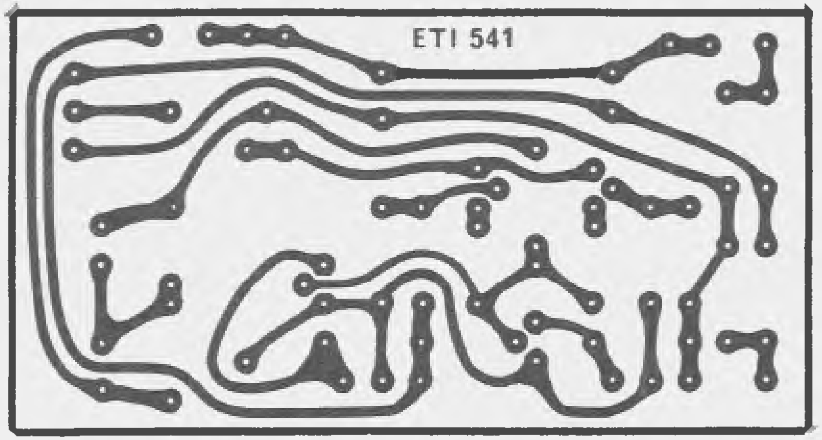
FOR MANUAL REVERSE CONTROLLER

Delete

R4, R8 and R9
C2 and C3
Diodes D3-D8
Transistors Q2, 4 and 6

If no loops are involved in the track layout SW4 and SW5 can be deleted on automatic reverse controller and SW5 on manual reverse controller.

For a second controller delete T1, SW1, D1-D4 and the power cord in the second controller.



Printed-circuit board layout ETI 541 train controller. Full size 65 x 105 mm.

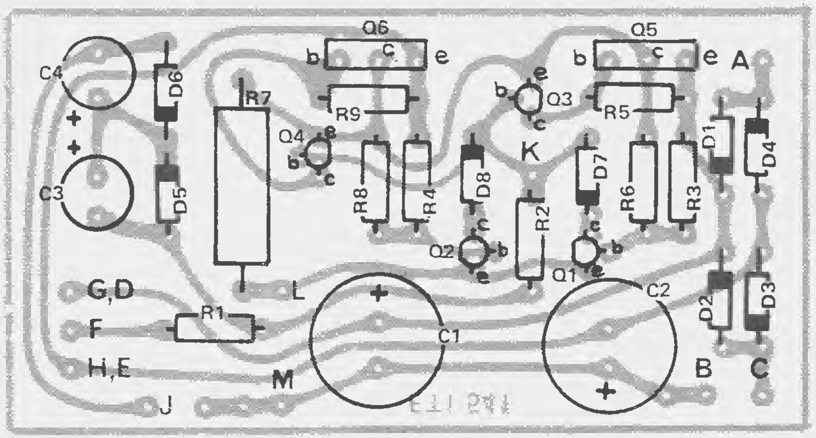


Fig. 3. Component overlay — auto reverse controller.

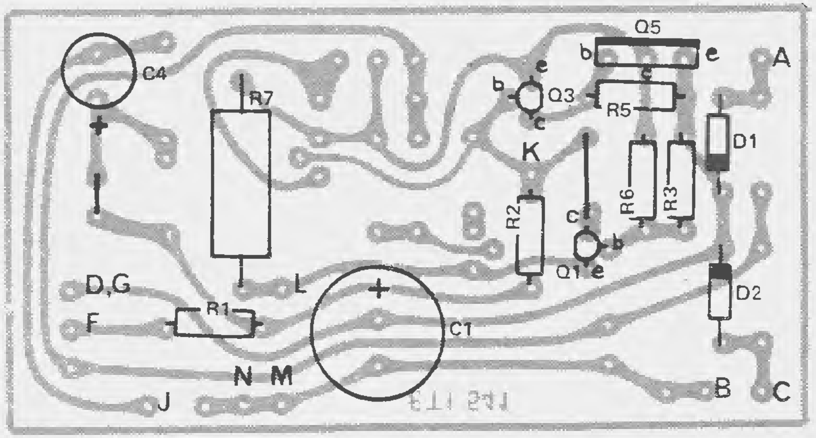


Fig. 4. Component overlay — simple controller.

Train controller

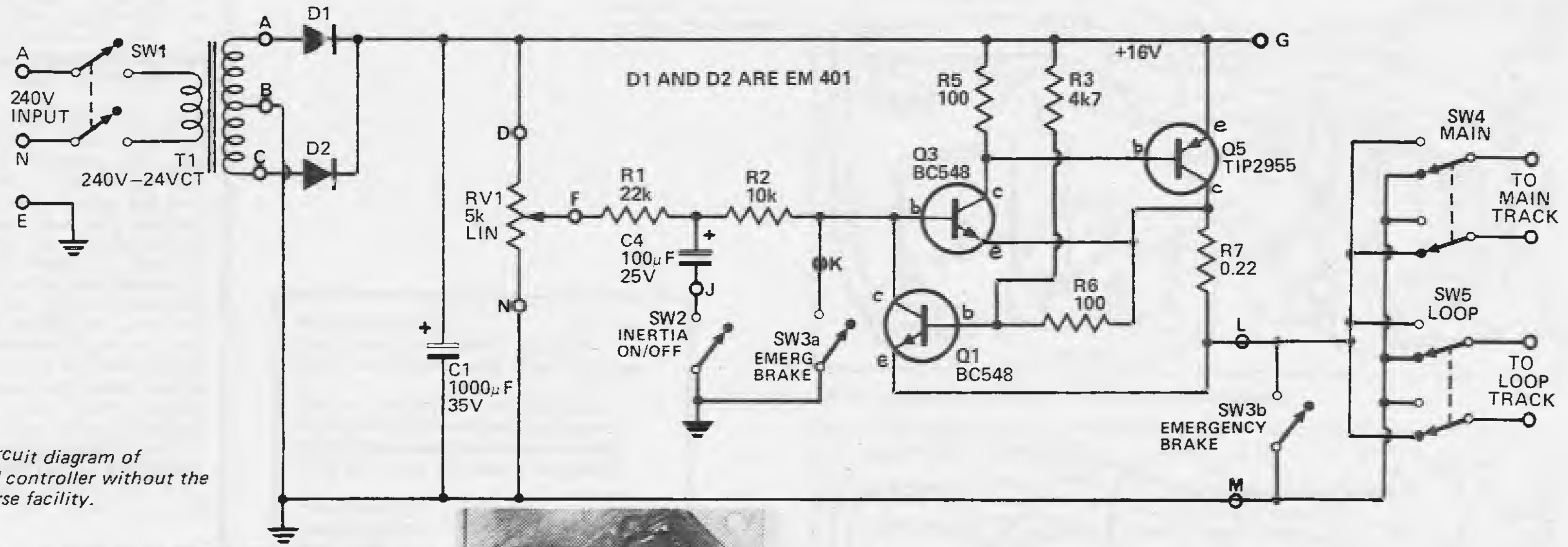
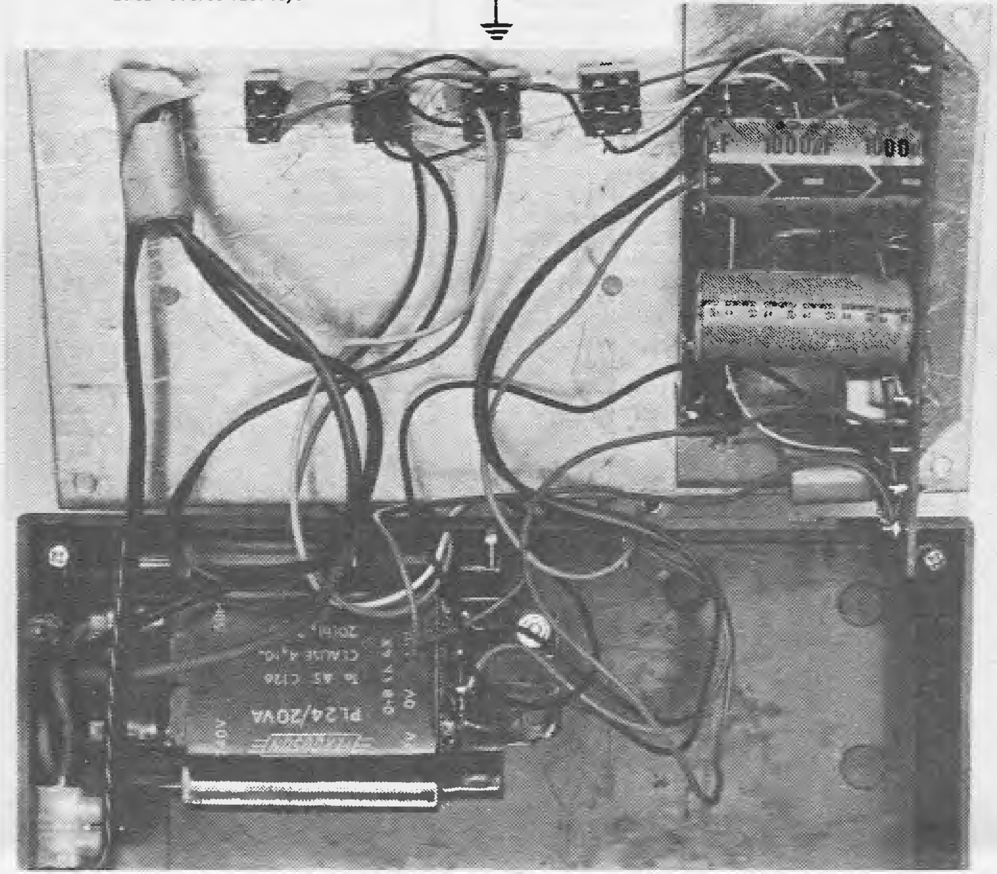
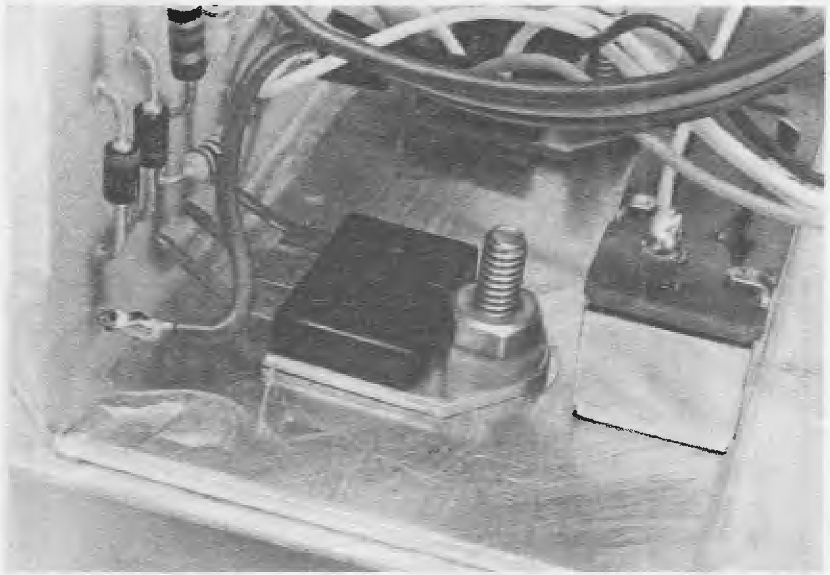


Fig. 5. Circuit diagram of simplified controller without the auto-reverse facility.





*The power transistors **are mounted** to a bracket with countersink bolts. They can, if desired, be mounted directly on the front panel. Note how the pcb is mounted – by epoxying to the bracket.*

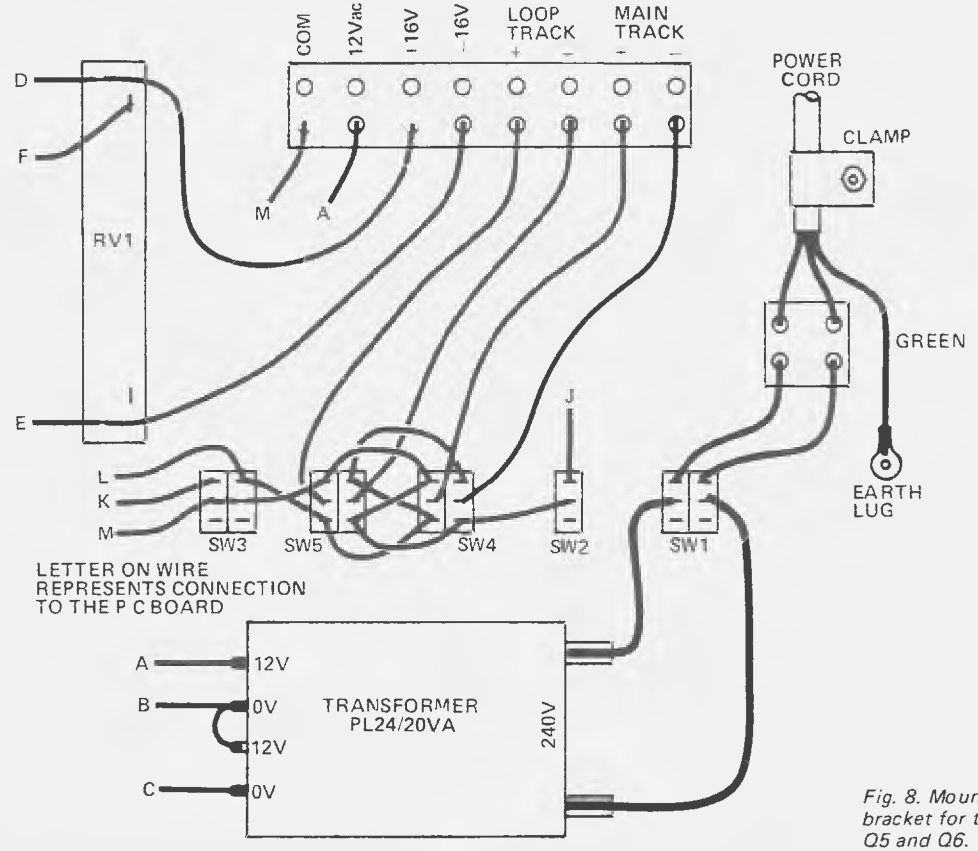
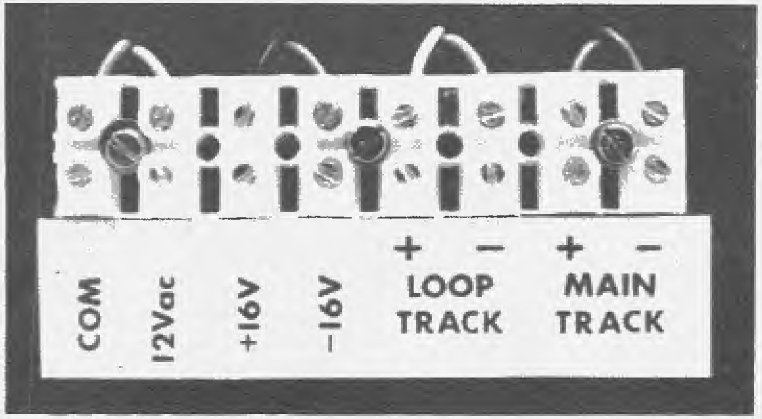


Fig. 7. Interconnection diagram for the auto-reverse controller given in the circuit of Fig. 2.



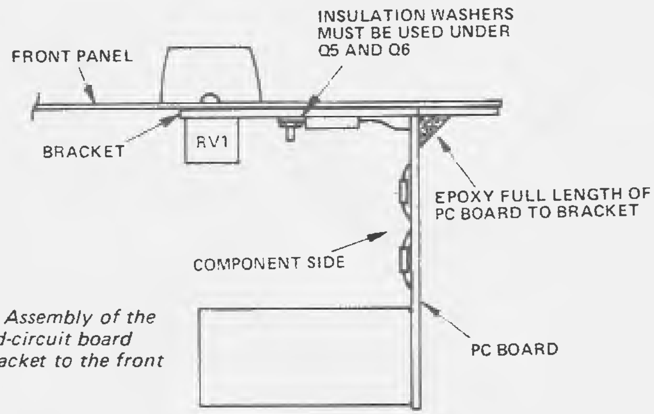


Fig. 6. Assembly of the printed-circuit board and bracket to the front panel.

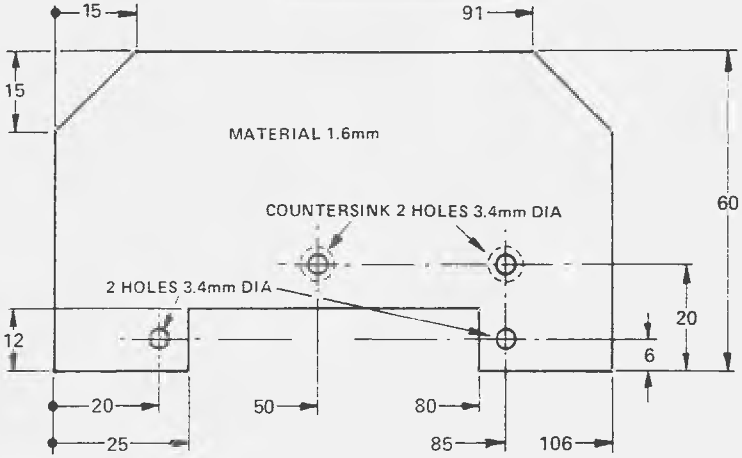


Fig. 8. Mounting bracket for transistors Q5 and Q6.

leave the loop then the train, once it passes the breaks in the track, will find the wrong polarity on the main track. It will be unable to continue in the same direction. To overcome this problem the main-track switch must be changed to 'reverse' whilst the train is within the loop. If the train enters the loop towards 'B' then the loop switch must be reversed before the train enters the loop. Once again the mainline polarity is reversed whilst the train is within the loop. Providing the section of the loop between 'A' and 'B' is longer than the train, loop operation will be simple and trouble free.

Simpler versions If all the facilities of the controller are not required then it may quite easily be simplified. If only a single direction is required from the throttle control then the same printed-circuit board and the circuit in Fig. 5. may be used. If loop operation is not required then the controller may be further simplified by deleting SW5 and the associated wiring.

CONSTRUCTION

We built our controller into a plastic zippy box with an aluminium lid. Some people may wish to build the controller into a complete control panel or some other box. This is quite acceptable as the method of construction is not criti-

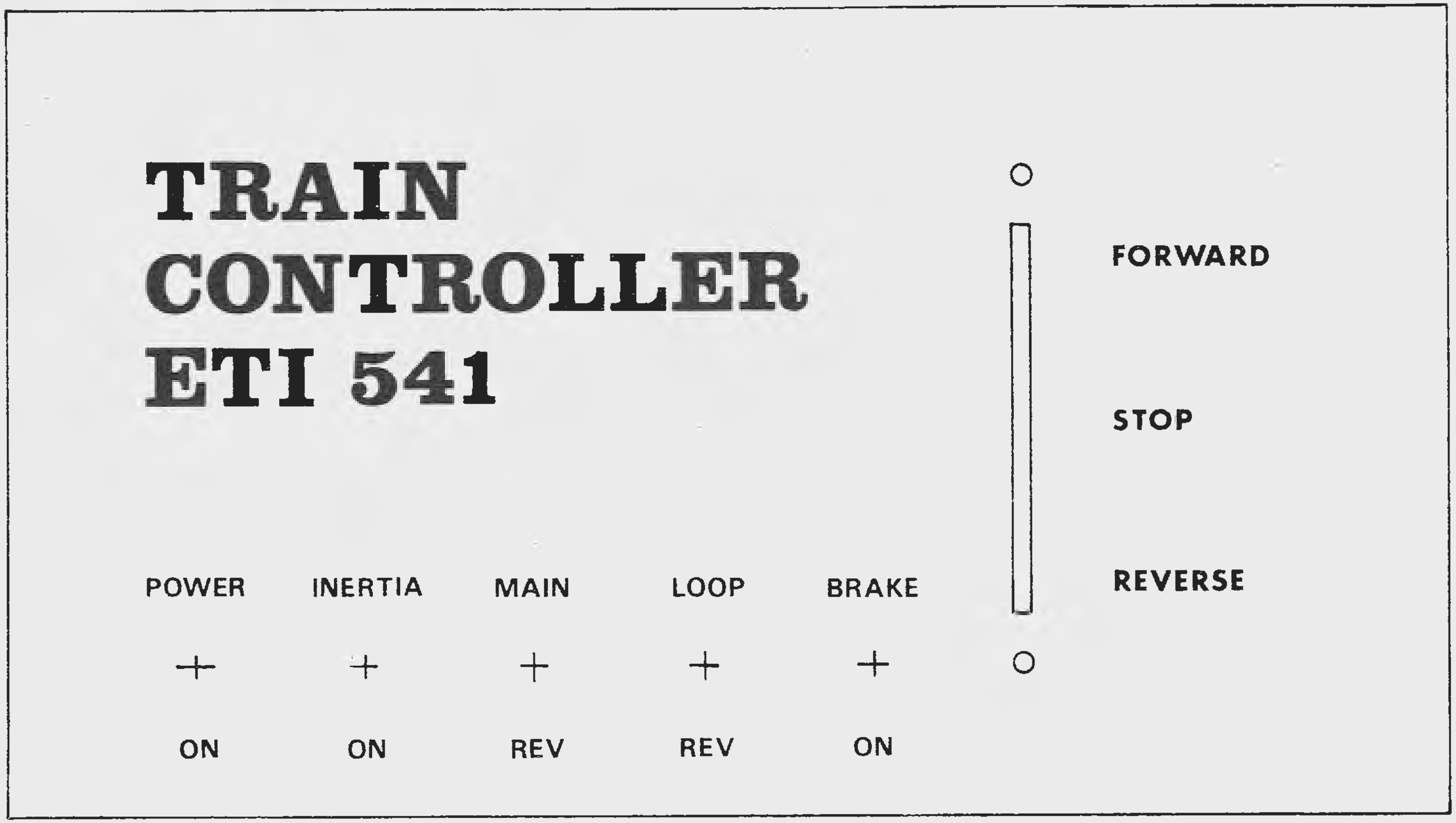


Fig. 9. Front panel artwork. Full size 191 x 107 mm.

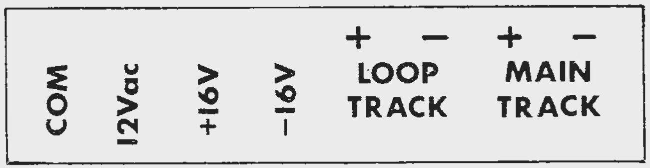


Fig. 10. Rear panel artwork.

cal. We suggest however that the printed circuit board specified be used as this greatly simplifies construction and minimizes the possibility of wiring errors.

Assemble the components to the printed-circuit board in accordance to the relevant component overlay. Watch that the polarities of components such as diodes, capacitors, and especially transistors, are correct. Note that two different pin connections are available in the BC548 and BC558 transistors, depending on the manufacturer. The Philips type is the one shown on the overlays.

A small bracket was used to hold the printed-circuit board in such a way as to hide the two screws which hold the power transistor. If two extra screw-heads on the front panel do not worry you, then this bracket need not be used. Bolt the power transistor onto the bracket using the insulation kit provided. The Scotchcal panel (if used) should now be fitted to the front panel and all holes drilled and the slot for the slide potentiometer cut. Mount the bracket to the rear of the front panel by means of the slide potentiometer and its mounting screws and then mount the rest of the switches. Drill a hole through the side of the plastic box for the power cord and then fit the cord, the cable clamp and the transformer into the box. Then mount the terminal block to the box and drill small holes for the wires from inside the box to be terminated to it. Finally wire the complete unit and test it.

Once sure that the controller works as it should the board edge should be glued to the front panel (or bracket) with a little epoxy glue. Once this has dried, and you are sure that there is a seal all along the edge of the board, pour epoxy glue along the join so as to form a fillet of glue about 5 to 10 mm wide. (A piece of sticky tape at either end will prevent the glue from running out at the ends). Once the glue has dried the completed front panel assembly may be screwed into the box. Add the rear panel label and the unit is ready for use.

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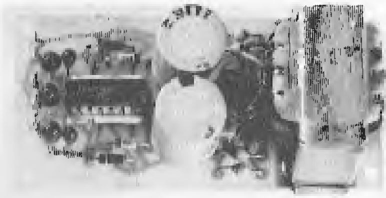

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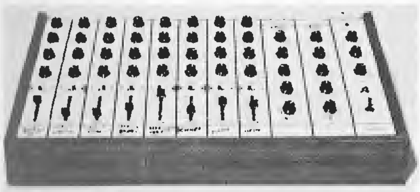

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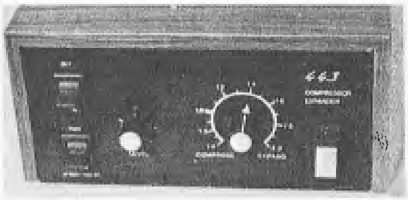

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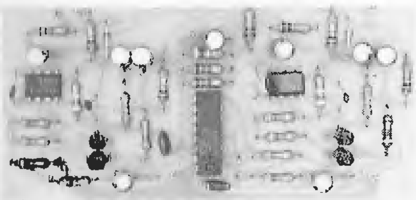

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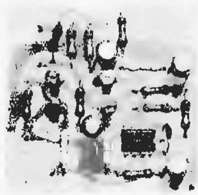

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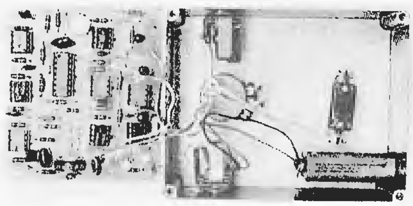

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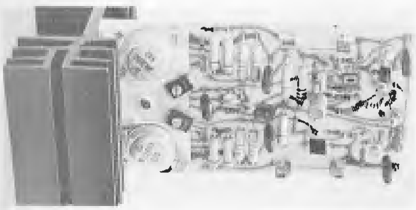

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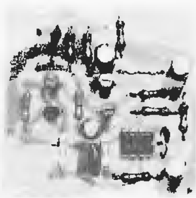

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